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Individual Differences in Executive Functioning and Psycho-emotional Well-being and the Impact of Acute Exercise on Children and Youth with ADHD

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Abstract

Short bouts of exercise can improve inhibitory control in children with Attention Deficit Hyperactivity Disorder (ADHD). However, individual differences among children with ADHD may impact the effectiveness of exercise interventions. We investigated how individual differences in inhibitory control, mood, and self-efficacy impact the efficacy of acute exercise among children with ADHD. Sixteen participants (ages 10-14) completed two interventions: 10 minutes of exercise and 10 minutes of silent reading (control). Inhibitory control was assessed prior to the intervention, immediately after the intervention, and after a 10-minute delay. Results suggested that participants with lower initial inhibitory control benefited more from exercise than participants with higher initial inhibitory control. Exercise reduced any initial benefit of a more positive mood state on inhibitory control, whereas self-efficacy had no effect on inhibitory control. This study demonstrates that individual differences in executive functioning and psycho-emotional well-being can alter the impact of exercise on children with ADHD.

Keywords

Exercise

Executive functioning

Inhibitory control

Attention deficit hyperactivity disorder

Cognition

Mood

Self-efficacy

Children & adolescents

Summary for Lay Audience

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders in children. Children with ADHD have difficulty focusing and regulating their emotions and behaviours. ADHD is typically treated with medication. Though this is often effective, it is also associated with negative side effects. Prior research shows that an additional way to support children with ADHD is through exercise. Short bouts of exercise can lead to improvements in inhibitory control—a cognitive ability involving the control of impulsive responses—which is a key area of difficulty for children with ADHD. However, even if exercise is generally beneficial, not all children with ADHD are likely to be impacted the same way.

This thesis explored several individual differences that could impact how children with ADHD respond to exercise. Specifically, we considered inhibitory control, mood, and self-efficacy (feelings of confidence in one's abilities). Sixteen children with ADHD participated in the study. Each participant's mood, self-efficacy, and inhibitory control were measured at the beginning of the study. Then, they rode a stationary bike for 10 minutes. Inhibitory control was measured again right after biking and after a 10-minute delay. On a separate day, the same participants completed the same protocol, except instead of exercise, they read silently for 10 minutes.

We found that participants who began the study session with lower levels of inhibitory control improved more on their inhibitory control after exercise than participants who began the study session with higher levels of inhibitory control. When participants read silently instead, neither group improved. Also, participants who were in a more positive mood had better inhibitory control initially, but after exercise mood did not impact their performance. This

suggests that exercise may be mitigating the effect of mood on inhibitory control. Finally, self-efficacy had no impact on how children with ADHD responded to exercise. These results show that exercise affects some children with ADHD differently than others, and that by identifying certain individual difference factors we can hopefully offer greater access to exercise interventions for children who need it the most.

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Individual Differences in Executive Functioning and Psycho-emotional Well-being and the Impact of Acute Exercise on Children and Youth with ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders in children and youth. It is characterized by inattention, hyperactivity, and impulsive behaviour (American Psychiatric Association, 2013). Children with ADHD experience high emotional reactivity and emotional dysregulation, impairments in academic and psychosocial functioning, and difficulties with executive functions (Morris et al., 2020). Executive functions are the cognitive activities involved in regulating intentional thoughts and behaviours, including core skills in inhibitory control, working memory, and cognitive flexibility (Freidman & Miyake, 2017). ADHD is most commonly treated with medication, but undesirable side effects have led to substantial interest in alternative and adjunct interventions. One proposed non-pharmaceutical intervention is exercise, which has received extensive support in the literature (Berwid & Halperin, 2012; Pontifex et al., 2013; Neudecker et al., 2019; Cerrillo-Urbina et al., 2015). However, little attention has been paid to the individual difference factors which may influence the effectiveness of exercise interventions for mitigating ADHD symptoms. This is an important area to investigate because individual characteristics often impact the effectiveness of interventions (Snow, 1991), yet this has rarely been investigated in the context of exercise interventions.

This thesis will address this problem by examining the impact of several individual difference factors on the effectiveness of exercise interventions in children with ADHD. Specifically, this thesis will examine how individual differences in inhibitory control, mood, and self-efficacy may alter the response of children with ADHD to a short bout of exercise. The following sections will describe current interventions for ADHD, executive functions and their contribution to ADHD symptomology, the impact of exercise on executive functioning in individuals with and without ADHD, how psycho-emotional factors such as mood and self-efficacy impact executive functioning, and how individual differences among children with ADHD may impact their receptivity to exercise interventions.

Impact of ADHD and Treatment Options

ADHD is a common neurodevelopmental disorder with a prevalence rate of approximately 5% (Polanczyk et al., 2007; Canadian Mental Health Association, 2014). The key symptoms of ADHD include severe inattention, hyperactivity, and deficits in impulse control that have an impact on everyday functioning (American Psychological Association, 2013). ADHD is associated with long-term challenges in academics, job success, and personal relationships (Halleland et al., 2019; Johnson et al., 2020). Individuals with ADHD have difficulty in cognitive, behavioural, and emotional areas of functioning. In terms of cognitive function, the key deficits are in executive functioning, which are essential for organization, focus, and higher-order thinking (Lambeck et al., 2011; see next section for an overview of executive functioning). The behavioural difficulties faced by children with ADHD include hyperactivity, difficulty focusing on a single task (or focusing too intently on one task to the exclusion of other relevant tasks or information) and engaging in impulsive or risk-taking behaviours (Pollock et al., 2019; Ashinoff & Abu-Akel, 2019). ADHD also affects individuals' psycho-emotional functioning. Specifically, individuals with ADHD can struggle to regulate their emotions and may act impulsively based on strongly-felt emotional reactions (Burnford et al., 2015). Children with ADHD are also more likely to experience low self-esteem and peer problems, potentially as a result of stigmatization due to their ADHD symptoms (Harpin et al., 2016). Children with ADHD are more likely than typically developing children to have an additional psychological disorder, most commonly mood, anxiety, and conduct disorders (Spencer, 2006). It is important to recognize the broad impacts of ADHD, particularly when considering interventions. The most commonly used interventions for ADHD tend to target behavioural symptoms of hyperactivity and inattention, and may not adequately address cognitive and emotional needs.

Currently, the most common intervention for ADHD is medication, with approximately 70% of Ontario children and youth with a diagnosis of ADHD being prescribed medication for the disorder (Hauck et al., 2017). Stimulant medications such as methylphenidate and amphetamines are most commonly prescribed (Bachmaan et al., 2017). These medications work by affecting dopamine and norepinephrine levels in the prefrontal cortex, an area of the brain involved in executive functioning (Shier et al., 2013). Stimulant medications are effective at improving behavioural symptoms of ADHD, but may not lead to long-term academic improvements or to the alleviation of social or emotional symptoms, and they may not improve objectively measured executive functions (Hale et al., 2011; Chronis et al., 2006). Furthermore, as many as 30% of children with ADHD do not respond to medication (Chronis et al., 2006). Many parents of children with ADHD discontinue the use of their child's medication due to intolerable side effects (such as loss of appetite, difficulty sleeping, and changes in mood), a perception that the medication is not working, or negative views about stimulants (Toomey et al., 2012). Due to the challenges and limitations associated with medication, there is substantial interest in psychosocial treatments to be used in addition to or instead of medication.

Behaviour management treatments are the most common type of psychosocial treatment for ADHD. Often, these include behavioural parent training, in which caregivers are trained and supported to use effective behavioural management techniques with their children, such as identifying and altering the antecedents and consequences of undesirable behaviours (Chronis et al., 2006). Behavioural parent training is considered an evidence-based treatment for ADHD as it has been extensively studied and found to be beneficial for behavioural, and in some cases, socio-emotional symptoms (Evans et al., 2014). Other evidence-based psychosocial treatments include behavioural classroom management for school-age children and cognitive behavioural therapy for adolescents and adults (Young & Amarasinghe, 2010). Other treatments emerging with possible evidence for their effectiveness include mindfulness meditation, neurofeedback training, and exercise (Caincross & Miller, 2016; Evans et al., 2014; Berwid & Halperin, 2012).

Executive Functioning and its Role in ADHD

Executive functions can be thought of as the top-down processes that are necessary for tasks that require concentration and intentional action (Diamond, 2013). There are three core executive functions: inhibitory control, working memory and cognitive flexibility (Friedman & Miyake, 2017). Inhibitory control involves the ability to control one's attention and behaviour to refrain from acting on a prepotent response (Munakata et al., 2011). Working memory refers to the ability to temporarily store and manipulate information (Baddeley, 2010), while cognitive flexibility refers to abilities such as changing perspectives, switching tasks, or adjusting to new rules (Diamond, 2013). Strong executive functioning is associated with greater academic achievement, occupational success, and life satisfaction (Willoughby et al., 2019; Miller et al., 2012; Miley & Spinella, 2006). Meanwhile, impairments in executive functioning are associated with substance abuse, risk taking behaviour, marital dissatisfaction, and criminal activity (Diamond, 2013).

Difficulty with executive functioning is a central component of ADHD. Of the core executive functions, inhibitory control has been shown to present the greatest challenge for children with ADHD. Inhibitory control deficits distinguish children with ADHD from other groups, including children with conduct disorder, anxiety, autism, or reading disability, and typically developing children (McCandless & O'Laughlin, 2007; Lipszyc & Schacher, 2010; Guerts et al., 2004). In tasks of inhibitory control, children with ADHD make more errors, have slower reaction times, and have a more variable pattern of responding compared to typically developing children (Bohlin et al., 2004). Deficits in inhibitory control have also been proposed to underlie other executive functioning deficits in ADHD (Barkley, 1997). This pattern has been observed longitudinally, with deficits in inhibitory control prior to age 5 leading to a greater likelihood of general executive functioning deficits and ADHD symptoms at age 8 (Berlin et al., 2003; Campbell & von Stauffenberg, 2009). Inhibitory control deficits are also associated with more long-term challenges in reading, writing, and math, lower levels of academic skill, and a greater risk of unemployment (Johnson et al., 2020; Halleland et al., 2019; Bledsoe et al., 2010; Roell et al., 2017). However, there is evidence that executive functions, including inhibitory control, can be improved, both directly through training and practice, and indirectly through interventions such as mindfulness meditation or exercise (Diamond, 2013).

Exercise and its Impact on the Brain and Executive Functioning

Neurobiologically, executive functioning is supported, in large part, by a brain region known as the prefrontal cortex (Stuss, 2011). The prefrontal cortex supports executive functioning processes including attention, working memory, judgement, planning, and cognitive flexibility (Carpenter et al., 2000; Konishi et al., 1998). Individuals with ADHD have been found to have altered prefrontal cortical activity as well as impairments in executive functioning. Imaging studies have reported structural and functional differences in the prefrontal cortex in children with ADHD, which may explain the observed deficits in executive functioning (Vaidya, 2011).

During exercise, there is an increase in blood oxygenation to the prefrontal cortex (Byun et al., 2014). This increase in oxygenation may support executive functioning following the cessation of exercise, given that successful performance on cognitive tasks requires oxygenation within relevant neural regions to sustain metabolic activity and support neuronal function (Giles et al., 2014). During exercise, there is also an augmentation of neurotransmitters related to memory and attention, which leads to improved information processing and cognitive performance (Gligoroska & Manchevska, 2012). The role of the prefrontal cortex in executive functioning, and the changes that occur in this area during exercise, may help explain the connection between exercise and positive changes in executive functioning.

Both long-term and short-term exercise is beneficial for cognitive functioning across the lifespan (Erikson et al., 2019). Exercise may be especially beneficial during childhood, with children experiencing boosts in a variety of cognitive areas, including executive functioning, and perceptual, verbal, and academic skills as a result of long-term exercise engagement (Sibley & Etnier, 2003; Hillman et al., 2014; Tomporoski et al., 2008). However, even short bouts of exercise can lead to improvements in executive functioning in typically developing children (Ellemberg & St-Louis-Deschenes, 2010; Hillman et al., 2011).

Improvements in executive functioning related to exercise have also been observed in children with ADHD. In the longer-term, engaging in routine exercise has been associated with improvements in executive functioning. For example, a 12-week program of 30-minutes of daily exercise was found to improve attention and mood among children with ADHD (Hoza et al., 2014) and an eight-week program of 25-minutes of daily exercise was found to improve inhibitory control, teacher ratings of behaviour, self-esteem, and social skills (Smith et al., 2013). Even single bouts of acute exercise appear to be beneficial for children with ADHD, with several studies finding that acute exercise facilitates inhibitory control, processing speed, and cognitive flexibility in children with ADHD (Ludyga et al., 2017; Piepmeier et al., 2015; Chang et al., 2012). For example, Pontifex and colleagues (2013) found that typically developing children and children with ADHD both demonstrated improved inhibitory control, reading comprehension, and arithmetic following 20 minutes of moderate-intensity exercise, compared to a sedentary control activity. These improvements were reflected in changes at the neurobiological level using electroencephalography (EEG). Both groups of participants showed larger P3 amplitudes and shorter P3 latencies following exercise, which are neuroelectric indicators of attentional allocation and processing speed (Pontifex et al., 2013). The objective neurobiological response lends further support to the notion that exercise may be improving executive functioning by altering related brain areas.

Exercise has also been observed to lead to psycho-emotional benefits for individuals with ADHD, including positive changes in mood. Adolescents with ADHD who are more physically active in the long term have been found to experience lower levels of depressed affect and internalizing symptoms compared to less active adolescents (Gawrilow et al., 2016; Cornelius et al., 2017). In terms of acute exercise, state levels of depression, fatigue, and motivation were improved following a session of acute exercise in a study of adults with ADHD (Fritz & O’Connor, 2016). This suggests that exercise can improve mood in addition to executive functioning, which is important for the ADHD population as they typically experience both emotional and cognitive dysfunction.

Psycho-emotional Well-being and Executive Functioning

Factors related to psychological or emotional states can also impact executive functioning. Specifically, mood appears to impact executive functioning, although the direction and extent of this relationship is unclear (Mitchell & Phillips, 2007). Some research suggests that positive mood impairs executive functioning, although this may depend on the specific type of executive function considered (Mitchell & Phillips, 2007). Other work shows that positive mood negatively impacts working memory, but does not impair inhibitory control (Martin & Kerns, 2011). Cognitive flexibility has also been shown to be both positively and negatively impacted by positive mood, depending on the task used (Dreisbach & Goschke, 2004; Phillips et al., 2002). Positive mood may disrupt working memory processes due to the spread of semantic activation that has been observed in individuals in a positive mood state (Martin & Kerns, 2011). When activation is more diffuse, it may become more difficult to keep items in working memory sufficiently activated, thus impairing performance on working memory tasks (Martin & Kerns, 2011). The observed impairments in working memory when individuals are in a positive mood state may help explain findings of similar impairments in cognitive flexibility because of the overlap between these constructs (Friedman & Miyake, 2017). Nevertheless, each core executive function is still a unique construct (Diamond, 2013), which may explain the discrepancies in how positive mood affects different aspects of executive functioning. There are also inconsistencies in how negative mood impacts executive functioning, with some earlier research suggesting that negative mood does not impact executive functioning (Mitchell & Phillips, 2007) but more recent work suggesting that negative mood impairs executive functioning (Buelow, 2015; Gabel & McAuley, 2018). Overall, the literature on the direct impact of positive and negative mood on executive functioning in children and youth with ADHD is limited in quantity and there are substantial inconsistencies within the findings.

Mood has been examined as a mediator in the relationship between exercise engagement and improvements in aspects of cognitive performance, including executive functioning. Because depression is associated with broad deficits in executive functioning and other cognitive areas such as processing speed, autobiographical memory, and general intelligence (Austin et al., 2001; Ahern & Semkovska, 2017), and exercise is beneficial for both mood and executive functioning, some researchers have questioned whether positive changes in mood due to exercise could lead to the observed improvements in executive functioning following exercise (Stillman et al., 2016). Only a small number of studies have examined this potential relationship directly. One study found that lower levels of exercise in older adults predicted poorer performance on tasks of visual memory and cognitive flexibility, and that this relationship was mediated through higher levels of depressive symptomology (Vance et al., 2005). This means that low levels of exercise may lead to more depressive symptoms, which may lead to worse executive functioning. However, other studies have failed to replicate this finding (Robitaille et al., 2014). Other work has found that individuals with more depressive symptoms at baseline showed greater gains in working memory following a long-term exercise intervention than those with fewer depressive symptoms at baseline (Williams & Lord, 1997). Overall, as with the research investigating the direct effect of mood on executive functioning, research examining mood as a mediator has been largely inconclusive. This line of research has also tended to examine long-term exercise, depressive symptoms, and older adults while little work has examined acute exercise, state level mood, or children (with or without ADHD).

Self-efficacy can impact aspects of cognition as well. Self-efficacy refers to the perception of one's ability to succeed in a specific setting or on a specific task (Themanson et al., 2011). It has been found to predict performance in a variety of cognitive domains, including mathematical reasoning, linguistic reasoning, analytic reasoning, and memory (Bandura, 1993; Bouffard-Bouchard, 2001). Less work has considered the contribution of self-efficacy to executive functioning; however, state self-efficacy has been linked to improved accuracy following errors on a task of inhibitory control, suggesting that there may be a link between self-efficacy and executive functioning (Themanson et al., 2011). Self-efficacy related to academic skills has also been positively associated with executive functioning in children with ADHD (Gamin & Swiecicka, 2015). However, the role of self-efficacy in executive functioning has rarely been considered in children with ADHD, and the question remains whether variance in state levels of self-efficacy will impact the potential benefit of exercise on executive functioning.

Individual Differences and Response to Exercise

Children with ADHD are not a homogeneous group. Although all individuals with ADHD are often grouped together in research, there are three distinct presentations of the disorder according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) – primarily hyperactive-impulsive, primarily inattentive, and combined presentation (American Psychiatric Association, 2013). Individuals diagnosed with each subtype presentation differ in symptoms related to inattention and hyperactivity, and exhibit differences in levels of emotional reactivity and executive functioning (Conzelmann et al., 2009; Martel et al., 2007). This means that although all children with ADHD share some core deficits, there are a variety of possible symptom presentations and developmental pathways which differ between individuals. For example, while the disorder is characterized by deficits in executive functioning, the extent of these deficits varies. Children with ADHD perform worse on average on executive functioning tasks compared to typically developing children, but there is considerable variation on task performance within the ADHD group (Lambeck et al., 2011). Additionally, the degree to which children with ADHD experience symptoms of emotional dysregulation is variable. Between 14 and 30% of youth with ADHD score below the 10th percentile for emotional control, while others score in the normal range (Bunford et al., 2015). These differences may be related to the effectiveness of treatments, as individuals with fewer affective symptoms have been found to respond better to both behavioural and pharmacological interventions for ADHD (Waxmonsky et al., 2008). It is currently unclear whether this same pattern will apply to exercise interventions, or if other individual differences such as in inhibitory control and other aspects of psycho-emotional well-being will impact treatments in a similar way.

The numerous possible individual differences among children with ADHD could influence individuals' response to exercise interventions as well. Considering an Aptitude by Treatment Interaction (ATI) framework may be beneficial for examining this possibility. The ATI framework describes individual aptitudes (i.e., cognitive, motivational, or personality factors) and how they influence the outcome of a treatment (Snow, 1991). ATI addresses the issue of fit between an individual and a situation, where the response to the situation depends on the characteristics of the individual (Snow, 1991). ATI has been extensively studied in the context of educational and psychotherapeutic interventions, but has been less commonly applied to exercise interventions.

Some research has examined the impact of individual differences in baseline executive functioning on changes in executive functioning following an acute exercise intervention. For example, when typically developing children were grouped based on performance on an inhibitory control task, lower performers showed greater improvements in inhibitory control following an acute bout of moderate-intensity exercise than higher performers (Drollette et al., 2014). Similarly, adults with lower baseline working memory function showed larger increases in working memory following acute exercise compared to those with higher baseline working memory function (Sibley & Beilock, 2007; Yamazaki et al., 2018). This suggests that exercise interventions may be more beneficial for individuals with lower baseline executive functioning.

No work has yet examined individual differences in either executive functioning or psycho-emotional well-being in children with ADHD on the effectiveness of exercise interventions, despite the potential for these factors to impact the efficacy of these interventions for this population. As discussed above, children with ADHD are not a homogenous group and show substantial variation in executive and psycho-emotional functioning. This means that although children with ADHD generally show improvements in executive functioning following exercise (ex. Pontifex et al., 2013; Ludyga et al., 2017), they may not all respond in exactly the same way. It is important to determine which individual difference factors affect the responsiveness to exercise interventions, as this information could be used to identify and target individuals who would benefit most from exercise interventions.

Current Study

The current study investigated the impact of individual differences in executive functioning and psycho-emotional well-being on the effect of an acute bout of exercise on executive functioning in children with ADHD. Specifically, we considered the effect of differences in baseline inhibitory control and differences in state mood and self-efficacy. In a within-subjects design, children with ADHD (ages 10-14) completed a 10-minute moderate intensity exercise session and a control session one week apart. Measures of mood and self-efficacy were collected at the beginning of each session. Participants completed a measure of inhibitory control before the intervention, immediately post-intervention, and after a 10-minute delay.

Research Questions and Hypotheses

1) *How do individual differences in inhibitory control influence the effect of acute exercise on executive functioning?*

We predicted that individuals with lower baseline inhibitory control would show greater improvements in inhibitory control following an acute bout of exercise. This has been observed in typically developing children (Drollette et al., 2014) and is consistent with similar findings in adults (Sibley & Beilock, 2007; Yamazaki et al., 2018). This is an especially pertinent question to examine in the ADHD population due to the deficits in inhibitory control and other executive functions which characterize the disorder. We expect that gains in inhibitory control after exercise will be greatest for the children with the largest initial inhibitory control deficits.

2) *How do individual differences in mood impact the effect of acute exercise on executive functioning?*

Although mood is generally improved by exercise, it is currently unclear how baseline mood state affects changes in inhibitory control following exercise. Some evidence suggests that individuals who begin an exercise regimen in a more depressed state will see more executive functioning improvements than those with fewer depressive symptoms (Vance et al., 2005; Williams & Lord, 1997). Other work suggests that positive mood may have an impairing effect on executive functioning (Mitchell & Phillips, 2007). Taken together, these previous findings support the prediction that individuals in a more negative baseline mood state will see larger gains in inhibitory control performance compared to individuals in more positive moods following a short bout of exercise. However, the analysis of this question remains largely exploratory due to the conflicting nature of the existing evidence in this domain.

3) *How do individual differences in self-efficacy impact the effect of acute exercise on executive functioning?*

We predicted that higher self-efficacy would positively impact the effect of an acute bout of exercise on inhibitory control, meaning that individuals scoring higher in state self-efficacy should demonstrate greater improvements in inhibitory control following exercise. This is supported by evidence that self-efficacy enhances cognitive function (Bouffard-Bouchard, 2001; Bandura, 1993). Individuals high in self-efficacy may also invest more effort in the exercise task because they will be confident in their ability to perform well (Gao et al., 2011). This could lead to a larger effect of exercise on inhibitory control for individuals higher in self-efficacy, as they may reap more benefits from the exercise itself.

Chapter 2: Method

Participants

Participants were 16 children diagnosed with ADHD. A sample size calculation was performed using G*Power with medium to large effect size Cohens $f = 0.4\text{-}.05$ (Salkind, 2010), power of 0.8, alpha of 0.05. This indicated that 30 participants were needed. Our goal was to recruit 30 participants, but we were only able to recruit 16 due to COVID-19 halting data collection. Data collection occurred between May 2019 and March 2020. Participants ranged in age from 10 to 14 years ($M = 11.38$, $SD = 1.5$). There were 11 male participants and 5 female participants, which reflects the typical gender discrepancy in ADHD diagnosis rates (Rucklidge, 2010). Participants were recruited through the Child and Youth Development Clinic and the Merrymount Research and Education Center at Western University. Exclusion criteria included children who were not fully literate, did not speak English, or who were colour blind, as these characteristics could interfere with the ability to complete the Stroop task. See Table 1 for a detailed description of participant demographics.

Measures

Stroop Task

The Stroop task is a measure of inhibitory control. It requires the inhibition of automatic word reading and is a valid and commonly used measure of inhibition in children (MacLeod, 1991; Lansbergen et al., 2007). Participants were asked to name the printed colours in a list of colour words while ignoring the content of the words themselves. In the incongruent version of the task (see Appendix A), if participants saw the word ‘blue’ printed in orange ink, they should say ‘orange’. Participants were instructed to name the colours as quickly as possible without making mistakes for 2.5 minutes. The proportion of correct responses was used as the task score.

Mood Scale

Participants completed the "Adapted Version of the Profile of Mood States" questionnaire (Williamson et al., 2001; see Appendix B). On this measure, participants rated the extent to which they were feeling eleven emotions (Active, Awake, Bored, Energetic, Excited, Friendly, Happy, Lonely, Sad, Tired, and Unhappy). Responses were recorded on a 5-point Likert scale (1=not at all, 5=extremely). The experimenter read each item aloud and the participant responded orally.

General Self-Efficacy Scale

Participants also completed the "General Self-Efficacy Scale", a questionnaire measure of general self-efficacy (Chen et al., 2001; see Appendix C). The measure includes items related to perceptions of one's ability to achieve goals, perform well on tasks, and obtain important outcomes. The questionnaire has eight statements to which participants responded on a 5-point Likert scale (1=strongly disagree; 5=strongly agree). Example statements include "I will be able to successfully overcome many challenges" and "When facing difficult tasks, I am certain that I will accomplish them". The experimenter read each statement aloud and the participant responded orally.

Design

This study used a within-subjects design in which all participants completed each experimental condition. The study included three sessions, each one week apart. The first session was for familiarization and the next two sessions were for the experimental conditions. These conditions included the exercise session and a silent reading control session. The order of the experimental and control sessions was counterbalanced.

Procedure

Familiarization Day and Questionnaires

Child participants and their guardians visited the lab for approximately 45 minutes for an initial familiarization session. Experimenters explained the study's procedure and what to expect at each visit to the lab. Guardians were provided with a Letter of Information and Consent form and children were provided with an assent form. Children and guardians had the opportunity to ask questions and have their questions answered. After obtaining informed consent, the child participant went with one experimenter to complete familiarization tasks and the other experimenter stayed with the guardian while they completed questionnaires to verify their child's ADHD status and gather demographic information.

Guardian Protocol. Guardians completed the Vanderbilt Parent Rating Scale (VADPRS) and the Behavior Rating Inventory of Executive Functioning (BREIF). The VADPRS is a measure of ADHD symptomatology which includes items representing each of the 18 diagnostic criteria for ADHD from the DSM-5, as well as criteria for Oppositional Defiant Disorder and Conduct Disorder. Guardians rated the severity of each potential symptom on a four-point scale from "never" to "very often". ADHD is considered present if scores indicate that a behaviour occurs "often" or "very often" for the requisite number of items. See Table 2 for VADPRS results. The BRIEF is a measure of executive functioning in daily life which is commonly used in the assessment of ADHD. Individuals with ADHD typically score in the clinical range on this assessment due to deficits in executive functioning. It includes 86 items which measures eight aspects of executive functioning, including inhibition, shifting, emotional control, initiation, working memory, planning and organization, and self-monitoring. See Table 3 for BRIEF results. Guardians also completed a Demographics Questionnaire and a Medication

Questionnaire which were used to gather information about their child's age, sex, socioeconomic status, medication use, and diagnostic history. See Table 1 for demographic questionnaire results and see Table 4 for medication questionnaire results.

Child Protocol. Meanwhile, children completed additional questionnaires, baseline measurements, and practiced the study procedures. Children completed the *Physical Activity Questionnaire for Older Children* (PAQ-C; Kowalski et al., 2004), a questionnaire about the exercise they engaged in in the past week (see Appendix D). They also completed measures of physical fitness, including height and weight, standing long-jump, and grip strength (See Table 5). Standing long-jump is a commonly used measure of explosive leg power (Simpson et al., 2020) and grip strength is an indicator of global musculoskeletal health (Wind et al., 2010). The physical activity questionnaire and physical fitness measures were not used for analysis, but rather as descriptive measures of children's physical fitness status. Children also practiced the executive functioning and psycho-emotional measures they would be completing during the experimental and control sessions, including the Incongruent Stroop Task, and mood and self-efficacy measures. This was done to ensure that participants were comfortable with the tasks and to minimize practice effects. During the same session, children had the opportunity to practice using the stationary bike for 10 minutes to become familiar with it prior to the exercise session and to ensure that they were able to complete the task.

Experimental Session: Exercise

One week after the previous session, participants returned to the lab to complete the exercise intervention session (see Appendix E for a schematic of the procedure). To begin, participants completed the measures of self-efficacy and mood. Participants also completed the pre-intervention Incongruent Stroop Task.

Participants then completed the exercise intervention. They were instructed to cycle continuously for 10 minutes at a moderate intensity, as determined by 65-85% of the maximum heart rate for their age using the equation 208 – (0.7 x age; Machado et al., 2011). For example, for a 10-year-old, this is between 130-170 bpm. Stationary biking was chosen as the exercise task because it involves aerobic activity, meaning that it requires the use of large muscle groups, can be maintained continuously, and is rhythmic in nature. Aerobic exercise has been more consistently shown to improve cognitive function than other types of exercise such as stretching or resistance training (Chang et al., 2012b). Biking was chosen as the intervention activity in several previous studies with children with ADHD (ex. Pontifex et al., 2013; Ludyga et al., 2017). The 10-minute duration and moderate level of intensity were chosen because moderate intensity exercise has been found to be sufficient to promote boosts to executive functioning, and 10 minutes has been shown to be beneficial without being overly taxing to lower-fit participants (Chang et al., 2012b; Erikson et al., 2019).

Participants were instructed on how to use the stationary bike and were fitted with a fit-bit device on their wrist to monitor their heart rate. They were then asked to bike for 10 minutes. Every 1 minute, experimenters checked the participant's heart-rate. If they were below the designated level, they were encouraged to peddle faster. If their heart rate was too high, they were encouraged to peddle more slowly. At the same time every minute, experimenters asked participants to rate their level of perceived exertion based on the Ratings of Perceived Exertion Scale (0= nothing at all…5= strong …10= extremely strong; See Appendix F; Borg, 1998). A rating between 6 and 8 is considered to reflect moderate intensity. On average, participants' heart rate was 117.5bpm, or slightly below 60% maximum heart rate. The average perceived exertion was 7.1, suggesting that participants felt that they were working at a moderate intensity.

Following the 10 minutes of exercise, participants immediately completed the post-intervention inhibitory control task (Incongruent Stroop). Participants were then given a children's magazine to quietly read for 10 minutes. Participants then completed the post-intervention delay inhibitory control measure. The final task of the session was a second completion of the self-efficacy and mood measures.

Control Session: Silent Reading

The same protocol as the experimental session was followed (see Appendix E), with participants asked to read children's magazines instead of the 10 minutes of biking. Once the final task was completed, guardians and children were fully debriefed. They received their compensation and were thanked for their participation. Children were compensated $20/per day for participation; guardians received $20 total for participation.

Data Analysis

Scores on the individual difference measures – baseline inhibitory control, baseline self-efficacy, and baseline mood – were used to divide participants into two groups using a median split. The use of a median split to create discrete groups for data analysis has been done in prior research investigating similar research questions (see Drollette et al., 2014). Separate repeated measures ANOVAs were performed for each research question, with higher vs. lower baseline group as the between-subjects factor, time as a within-subjects factor, and inhibitory control as the dependent variable. Inhibitory control scores for all research questions were analyzed using a 2 (group: high baseline score, low baseline score) x 3 (time: pre-intervention, post intervention, post-intervention delay) model.

Table 1

Sample Demographics

	N (%)
Participant Age	
10	7 (43.75)
11	2 (12.5)
12	3 (18.75)
13	2 (12.5)
14	2 (12.5)
Participant Gender	
Male	11 (68.75)
Female	5 (31.25)
Guardian Employment Status	
Employed for wages	15 (93.8)
Homemaker	1 (6.3)
Guardian Education Level	
Some high school	1 (6.25)
High school	0 (0)
Some College, no degree	2 (12.5)
Trade/technical training	2 (12.5)
Associate degree	1 (6.25)
Bachelor’s degree	5 (31.25)
Master’s degree	4 (25)
Professional degree	1 (6.25)
Household Income	
Prefer not to say	2 (12.5)
< $30,000	1 (6.3)
$30,000 - $40,000	1 (6.3)
$40,000 - $50,000	1 (6.3)
$50,000 - $60,000	3 (18.8)

$60,000 - $70,000	3 (18.8)
$70,000 - $80,000	2 (12.5)
$80,000 - $90,000	0 (0)
>$100,000	3 (18.8)

Table 2

Vanderbilt Parent Rating Scale (VADPRS) Results

	N (%)
Inattentive	
Clinically significant	13 (81.25)
Not clinically significant	3 (18.75)
Hyperactive/impulsive	
Clinically significant	8 (50)
Not clinically significant	8 (50)
Oppositional-defiant disorder	
Clinically significant	8 (50)
Not clinically significant	8 (5)
Conduct disorder	
Clinically significant	1 (6.25)
Not clinically significant	15 (93.75)
Anxiety	
Clinically significant	1 (6.25)
Not clinically significant	15 (93.75)
Performance	
Clinically significant	13 (81.25)
Not clinically significant	3 (18.75)

Table 3

Behavior Rating Inventory of Executive Functioning (BREIF) Results

	N (%)
Inhibition	
Clinically significant	7 (43.75)
Not clinically significant	9 (56.25)
Self-Monitor	
Clinically significant	10 (62.5)
Not clinically significant	6 (37.5)
Behaviour regulation index	
Clinically significant	10 (62.5)
Not clinically significant	6 (37.5)
Shift	
Clinically significant	13 (81.25)
Not clinically significant	3 (18.75)
Emotional Control	
Clinically significant	9 (56.25)
Not clinically significant	7 (43.75)
Emotion regulation index	
Clinically significant	10 (62.5)
Not clinically significant	6 (37.5)
Initiate	
Clinically significant	8 (50)
Not clinically significant	8 (50)
Working Memory	
Clinically significant	10 (62.5)
Not clinically significant	6 (37.5)
Planning	
Clinically significant	8 (50)
Not clinically significant	8 (50)

Task Monitoring	
Clinically significant	11 (68.75)
Not clinically significant	5 (31.25)
Organization	
Clinically significant	8 (50)
Not clinically significant	8 (50)
Cognitive regulation index	
Clinically significant	13 (81.25)
Not clinically significant	3 (18.75)

Table 4

ADHD Diagnosis and Medication Questionnaire

	N (%)
Diagnosed with ADHD	
Yes	15 (93.75)
No	1 (6.25)
Age of Diagnosis	
4	1 (6.25)
6	2 (12.5)
7	4 (25)
8	3 (18.75)
9	4 (25)
11	1 (6.25)
Unsure	1 (6.25)
Age Symptoms Noticed	
2	1 (6.25)
3	3 (18.75)
4	3 (18.75)
5	2 (12.5)
6	2 (12.5)
7	1 (6.25)
8	3 (18.75)
No response	1 (6.25)
ADHD Subtype	
Predominantly Inattentive	3 (18.75)
Predominantly Hyperactive	1 (6.25)
Combined subtype	3 (18.75)
Unsure/No diagnosis given	9 (56.25)
Currently Taking Medication for ADHD	
Yes	9 (56.5)

No	6 (37.5)
No response	1 (6.25)
Other Diagnosis	
Yes	6 (37.5)
No	10 (62.5)
Which Other Diagnosis?	
Anxiety	5 (31.25)
Learning Disorder	1 (6.25)
Not Applicable	10 (62.5)
Medication for something other than ADHD	
Yes	2 (12.5)
No	14 (87.5)

Table 5

Participant Physical Fitness

	M (SD)
Height (cm)	144.01 (13.79)
Weight (kg)	47.15 (16.16)
Grip Strength – Right (lbs)	35.91 (11.08)
Grip Strength – Left (lbs)	33.73 (9.77)
Standing Long Jump (cm)	125.72 (29.30)

Chapter 3: Results

Research Question 1: How do individual differences in inhibitory control influence the effect of acute exercise on executive functioning?

To answer this question, we conducted two factorial repeated measures ANOVAs with a two level between-subjects factor of *group* (higher inhibitory control vs. lower inhibitory control) and a two level within-subjects factor of *time* (post-intervention vs. delay). The pre-intervention timepoint was not included in the model because it was used to create the between-subject groups. A median split was used to define the groups, with participants below the median score on Incongruent Stroop Task performance at the pre-intervention timepoint placed in the low inhibitory control group and those above the median placed in the high inhibitory control group. Separate ANOVAs were conducted for the experimental condition (exercise) and the control condition (silent reading). The outcome variable was the proportion of words correctly read on the Incongruent Stroop Task. Age and sex were included as covariates in the analyses if they were significant predictors of outcome. There were no extreme outliers consistent across outcome variables and conditions using the SPSS step of 1.5 x IQR (interquartile range).

In the experimental condition, there was no main effect of group, $F(1, 14) = 3.95$, $p = .07$, $\eta p^2 = 0.22$, no main effect of time, $F(1, 14) = 1.35$, $p = .27$, $\eta p^2 = 0.09$, and no interaction, $F(1, 14) = 0.66$, $p = .43$, $\eta p^2 = 0.05$. Age and sex were not included as covariates as they were not predictors of outcome (all *F*s < 3.81, all *p*s > .07). Planned independent t-tests revealed a significant difference between groups at pre-intervention, $t(14) = -4.17$, $p = .001$, but not at post-intervention, $t(14) = -0.81$, $p = .43$. After a delay, there was a significant difference between groups, $t(14) = -2.12$, $p = .05$.

In the control condition, there was a main effect of group, with the high baseline group performing better than the low baseline group, $F(1, 14) = 4.59$, $p = .05$, $\eta p^2 = 0.25$. There was also a main effect of time, with participants in both groups scoring higher at delay than post-intervention, $F(1, 14) = 4.76$, $p = .05$, $\eta p^2 = 0.25$. There was no interaction, $F(1, 14) = 0.27$, $p = .61$, $\eta p^2 = 0.02$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 0.92, all *p*s > .35). Planned independent *t*-tests revealed a significant difference between groups at pre-intervention, $t(14) = -4.98$, $p < .001$, and at post-intervention, $t(14) = -2.26$, $p = .04$, but not after a delay, $t(14) = -1.75$, $p = .10$.

Although there were no significant main effects or interactions in the exercise condition, the pattern of findings suggests that 10 minutes of exercise boosts inhibitory control for children and youth with ADHD, but only for those with lower baseline inhibitory control capacity. The exercise intervention appears to bring participants with lower inhibitory control up to the same level of performance as those with higher inhibitory control, thereby equalizing initial differences in inhibitory control among participants. However, these improvements are brief and no longer evident after a 10-minute delay. See Table 6 for descriptive statistics for research question 1 and see Figure 1 for a graphic representation of these results.

Table 6

Descriptive Statistics for Research Question 1

	Exercise M (SD)	N	Control M (SD)	N
Incongruent Stroop Proportion Correct - Pre				
Low Baseline Inhibitory Control	0.95 (.02)	8	0.93 (.03)	8
High Baseline Inhibitory Control	0.98 (.02)	8	0.98 (.01)	8
Total	0.96 (.02)	16	0.96 (.04)	16
Incongruent Stroop Proportion Correct - Post				
Low Baseline Inhibitory Control	0.96 (.03)	8	0.93 (.04)	8
High Baseline Inhibitory Control	0.97 (.02)	8	0.96 (.03)	8
Total	0.96 (.02)	16	0.95 (.04)	16
Incongruent Stroop Proportion Correct - Delay				
Low Baseline Inhibitory Control	0.94 (.02)	8	0.94 (.04)	8
High Baseline Inhibitory Control	0.96 (.02)	8	0.97 (.03)	8
Total	0.95 (.02)	16	0.96 (.04)	16

Figure 1

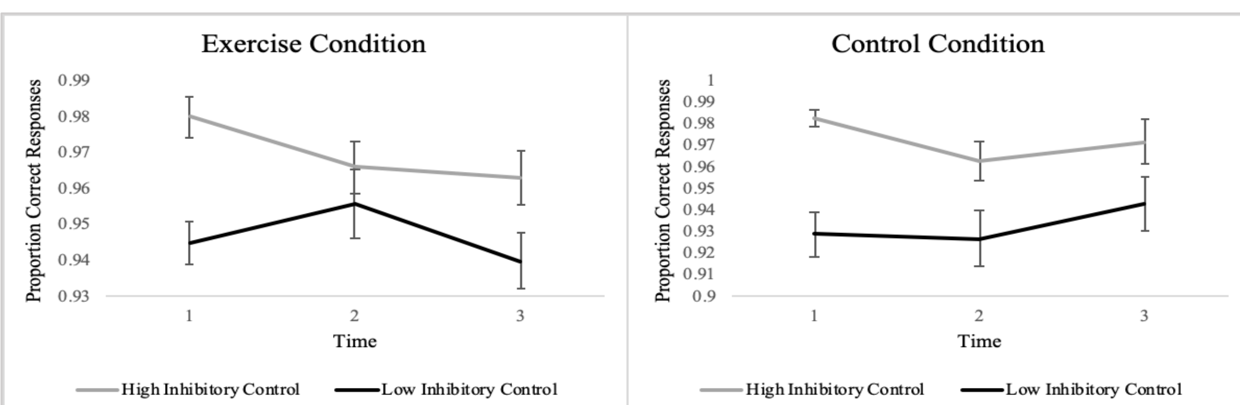

Figure 1. Exercise equalized differences in Stroop task performance between individuals higher and lower in inhibitory control immediately post-intervention. In the control condition,

participants high in inhibitory control maintained their advantage. Error bars represent standard error.

Research Question 2: How do individual differences in mood impact the effect of acute exercise on executive functioning?

To answer this question, we considered changes in both positive mood and negative mood. We conducted several factorial repeated measures ANOVAs with a two level between-subjects factor of *group* (high baseline mood score vs. low baseline mood score) and a three level within-subjects factor of *time* (pre-intervention vs. post-intervention vs. delay). Groups were defined using a median split, with participants below the median score on mood at pre-intervention placed in the low mood group and those above the median placed in the high mood group. In cases where participants were exactly at the median, they were randomly assigned to either the high or low mood group by SPSS statistical software, which in some cases resulted in uneven group sizes. Separate ANOVAs were conducted for the experimental condition and the control condition, as well as for positive mood and negative mood. The outcome variable was the proportion of words correctly read on the Incongruent Stroop Task. Age and sex were included as covariates in analyses if they were significant predictors of outcomes, and Greenhouse-Geisser was reported if sphericity was violated using Mauchly's Test of Sphericity. There were no extreme outliers consistent across outcome variables and conditions using the SPSS step of 1.5 x IQR (interquartile range).

In the experimental condition for positive mood, there was no main effect of group, $F(1, 14) = 1.33$, $p = .27$, $\eta p^2 = 0.09$, and no main effect of time, $F(2, 28) = 2.40$, $p = .11$, $\eta p^2 = 0.15$, but there was an interaction, $F(2, 28) = 3.82$, $p = .03$, $\eta p^2 = 0.21$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 3.55, all *p*s > .08). Planned independent *t*-tests revealed a significant difference between groups at pre-intervention, $t(14) = -$

2.44, $p = .03$, but not at post-intervention, $t(14) = -1.20$, $p = .25$, or after a delay, $t(14) = 0.75$, $p = .47$.

In the control condition for positive mood, there was no main effect of group, $F(1, 14) = 1.61$, $p = .23$, $\eta p^2 = 0.10$, no main effect of time, $F(1.42, 19.84) = 1.01$, $p = .36$, $\eta p^2 = 0.07$, and no interaction, $F(1.42, 19.84) = 0.75$, $p = .44$, $\eta p^2 = 0.05$. Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated, $\chi^2(2) = 6.89$, $p = .03$, so Greenhouse-Geisser corrections were reported to adjust for lack of sphericity. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 0.68, all *p*s > .42). Planned independent *t*-tests did not reveal any differences between groups at pre-intervention, $t(14) = 0.17$, $p = .87$, post-intervention, $t(14) = 1.29$, $p = .22$, or delay, $t(14) = 1.48$, $p = .16$.

In the context of positive mood, these results suggest that exercise may be leveling the results of positive mood on inhibitory control, with participants experiencing high and low levels of positive mood performing more similarly on an inhibitory control task after exercise than before exercise.

In the experimental condition for negative mood, there was no main effect of group, $F(1, 14) = 0.37$, $p = .55$, $\eta p^2 = 0.03$, but there was a main effect of time, $F(2, 28) = 4.16$, $p = .03$, $\eta p^2 = 0.23$, and an interaction, $F(2, 28) = 12.79$, $p < .001$, $\eta p^2 = 0.48$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 1.91, all *p*s > .19). Planned independent *t*-tests revealed no difference between groups at pre-intervention, $t(14) = 1.55$, $p = .14$, but a significant difference post-intervention, $t(14) = 2.18$, $p = .05$, and after a delay, $t(14) = -2.34$, $p = .03$.

In the control condition for negative mood, there was no main effect of group, $F(1, 14) = 0.21$, $p = .65$, $\eta p^2 = 0.02$, no main effect of time, $F(1.26, 17.67) = 1.09$, $p = .33$, $\eta p^2 = 0.07$, and no interaction, $F(1.26, 17.67) = 1.99$, $p = .18$, $\eta p^2 = 0.12$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 0.96, all *p*s > .35). Planned independent *t*-tests did not reveal any differences between groups at pre-intervention, $t(14) = 0.55$, $p = .59$, post-intervention, $t(14) = -1.62$, $p = .13$, or after a delay, $t(14) = -0.11$, $p = .91$.

In the context of negative mood, these results suggest that being in a less negative mood conveys an advantage for inhibitory control immediately after exercise, but that being in a more negative mood is beneficial after a delay. Potential explanations for these findings will be described in the discussion. See Table 7 for descriptive statistics for research question 2, see Table 8 for descriptive statistics for mood scores, and see Figures 2 and 3 for a graphic representation of these results.

Table 7

Descriptive Statistics for Research Question 2

	Exercise M (SD)	N	Control M (SD)	N
Incongruent Stroop Proportion Correct - Pre				
Low Baseline Positive Mood	0.95 (.02)	9	0.96 (.04)	8
High Baseline Positive Mood	0.98 (.02)	7	0.96 (.03)	8
Total	0.96 (.02)	16	0.96 (.04)	16
Incongruent Stroop Proportion Correct - Post				
Low Baseline Positive Mood	0.95 (.03)	9	0.96 (.03)	8
High Baseline Positive Mood	0.97 (.02)	7	0.93 (.04)	8
Total	0.96 (.02)	16	0.95 (.04)	16
Incongruent Stroop Proportion Correct - Delay				
Low Baseline Positive Mood	0.96 (.02)	9	0.97 (.02)	8
High Baseline Positive Mood	0.95 (.02)	7	0.95 (.04)	8
Total	0.95 (.02)	16	0.96 (.04)	16
Incongruent Stroop Proportion Correct - Pre				
Low Baseline Negative Mood	0.97 (.02)	7	0.96 (.03)	8
High Baseline Negative Mood	0.96 (.02)	9	0.95 (.04)	8
Total	0.96 (.02)	16	0.96 (.04)	16
Incongruent Stroop Proportion Correct - Post				
Low Baseline Negative Mood	0.97 (.02)	7	0.93 (.04)	8
High Baseline Negative Mood	0.95 (.02)	9	0.96 (.03)	8
Total	0.96 (.02)	16	0.95 (.04)	16
Incongruent Stroop Proportion Correct - Delay				
Low Baseline Negative Mood	0.94 (.02)	7	0.96 (.03)	8
High Baseline Negative Mood	0.96 (.02)	9	0.96 (.04)	8
Total	0.95 (.02)	16	0.96 (.04)	16

Table 8

Descriptive Statistics for Mood

	Exercise M (SD)	N	Control M (SD)	*N*
Positive Mood				
High Positive Mood Group	4.33 (0.50)	7	4.40 (0.41)	8
Low Positive Mood Group	3.06 (0.50)	9	2.85 (0.75)	8
Total	3.61 (0.82)	16	3.63 (0.99)	16
Negative Mood				
High Negative Mood Group	1.93 (0.32)	9	1.93 (0.38)	8
Low Negative Mood Group	1.23 (0.18)	7	1.18 (0.13)	8
Total	1.63 (0.44)	16	1.55 (0.48)	16

Figure 2

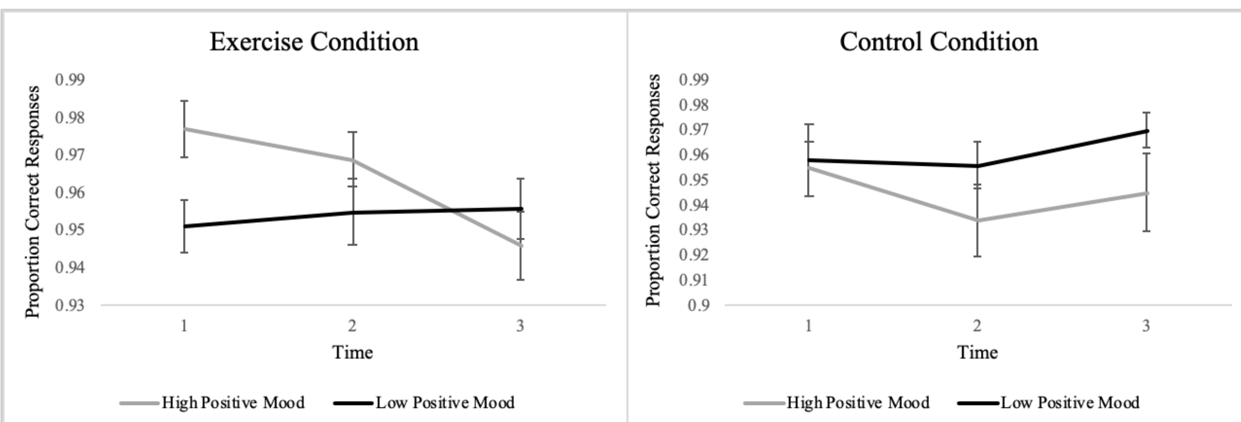

Figure 2. In the exercise condition, Stroop task performance significantly differed by positive mood at pre-intervention, but not post-intervention or delay. In the control condition, task performance did not differ by mood at any time. Error bars represent standard error.

Figure 3

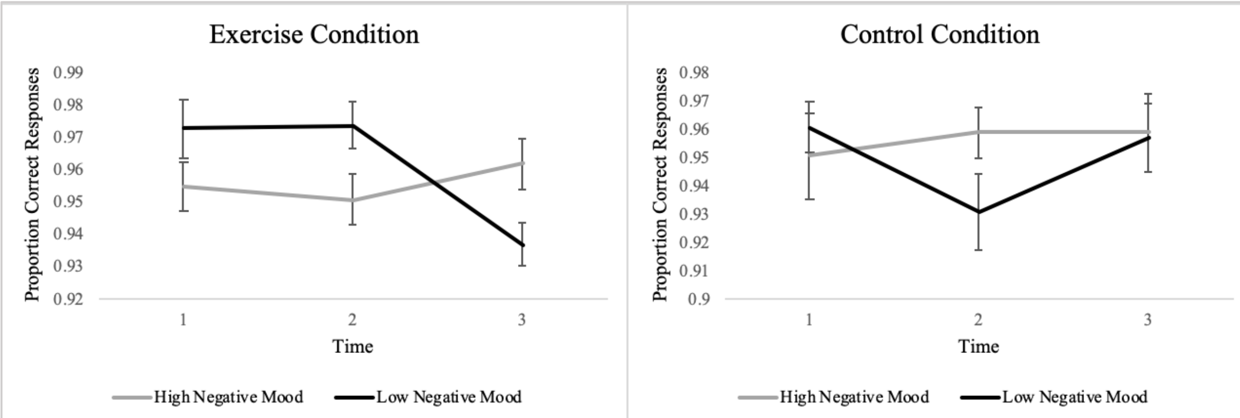

Figure 3. In the exercise condition, there was an interaction between time and group, with participants low in negative mood performing better at post-intervention, but participants high in negative mood performing better at delay. There were no differences between the groups in the control condition. Error bars represent standard error.

Research Question 3: How do individual differences in self-efficacy impact the effect of acute exercise on executive functioning?

To answer this question, we conducted two factorial repeated measures ANOVAs with a two level between-subjects factor of *group* (high baseline self-efficacy vs. low baseline self-efficacy) and a three level within-subjects factor of *time* (pre-intervention vs. post-intervention vs. delay). Groups were defined using a median split, with participants below the median score on self-efficacy at pre-intervention placed in the low self-efficacy group and those above the median placed in the high self-efficacy group. In cases where participants were exactly at the median, they were randomly assigned by SPSS statistical software to either the high or low self-efficacy group, which resulted in an uneven group size in the control condition. Separate ANOVAs were conducted for the experimental condition and the control condition. The outcome variable was the proportion of words correct on the Incongruent Stroop task. Age and sex were included as covariates in analyses if they were significant predictors of outcomes, and Greenhouse-Geisser was reported if sphericity was violated using Mauchly's Test of Sphericity. There were no extreme outliers consistent across outcome variables and conditions using the SPSS step of 1.5 x IQR (interquartile range).

In the experimental condition, there was no main effect of group, $F(1, 14) = 0.28$, $p = .61$, $\eta p^2 = 0.02$, no main effect of time, $F(2, 28) = 1.43$, $p = .26$, $\eta p^2 = 0.09$, and no interaction, $F(2, 28) = 0.68$, $p = .52$, $\eta p^2 = 0.05$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 1.67, all *p*s > .22). Planned independent *t*-tests revealed no significant differences between groups at pre-intervention, $t(14) = -1.01$, $p = .33$, post-intervention, $t(14) = -0.51$, $p = .62$, or delay, $t(14) = 0.32$, $p = .75$.

In the control condition, there was a main effect of group, $F(1, 14) = 5.12$, $p = .04$, $\eta p^2 = 0.27$, no main effect of time, $F(1.39, 19.42) = 0.69$, $p = .46$, $\eta p^2 = 0.05$, and no interaction, $F(1.39, 19.42) = 0.63$, $p = .49$, $\eta p^2 = 0.04$. Age and sex were not included as covariates as they were not predictors of outcome (all Fs < 4.40, all *p*s > .06). Planned independent t-tests did not reveal any differences between groups at pre-intervention, $t(14) = 0.88$, $p = .40$, but there was a difference at post-intervention, $t(14) = 2.47$, $p = .03$, and no difference after a delay, $t(14) = 1.69$, $p = .11$. These results suggest that individual differences in self-efficacy did not play a meaningful role in how children with ADHD respond to an acute exercise intervention. See Table 9 for descriptive statistics for research question 3, see Table 10 for descriptive statistics for self-efficacy scores, and see Figure 4 for a graphic representation of these results.

Table 9

Descriptive Statistics for Research Question 3

	Exercise M (SD)	N	Control M (SD)	N
Incongruent Stroop Proportion Correct - Pre				
Low Baseline Self-efficacy	0.96 (.03)	8	0.97 (.05)	6
High Baseline Self-efficacy	0.97 (.02)	8	0.95 (.03)	10
Total	0.96 (.02)	16	0.96 (.04)	16
Incongruent Stroop Proportion Correct - Post				
Low Baseline Self-efficacy	0.96 (.03)	8	0.97 (.01)	6
High Baseline Self-efficacy	0.96 (.02)	8	0.93 (.04)	10
Total	0.96 (.02)	16	0.95 (.04)	16
Incongruent Stroop Proportion Correct - Delay				
Low Baseline Self-efficacy	0.95 (.03)	8	0.98 (.02)	6
High Baseline Self-efficacy	0.95 (.02)	8	0.95 (.04)	10
Total	0.95 (.02)	16	0.96 (.04)	16

Table 10

Descriptive Statistics for Self-Efficacy

	Exercise M (SD)	N	Control M (SD)	*N*
Self- Efficacy				
High Self-Efficacy Group	4.27 (0.37)	8	4.29 (1.35)	10
Low Self-Efficacy Group	3.04 (0.53)	8	3.02 (0.66)	6
Total	3.65 (0.77)	16	3.82 (0.81)	16

Figure 4

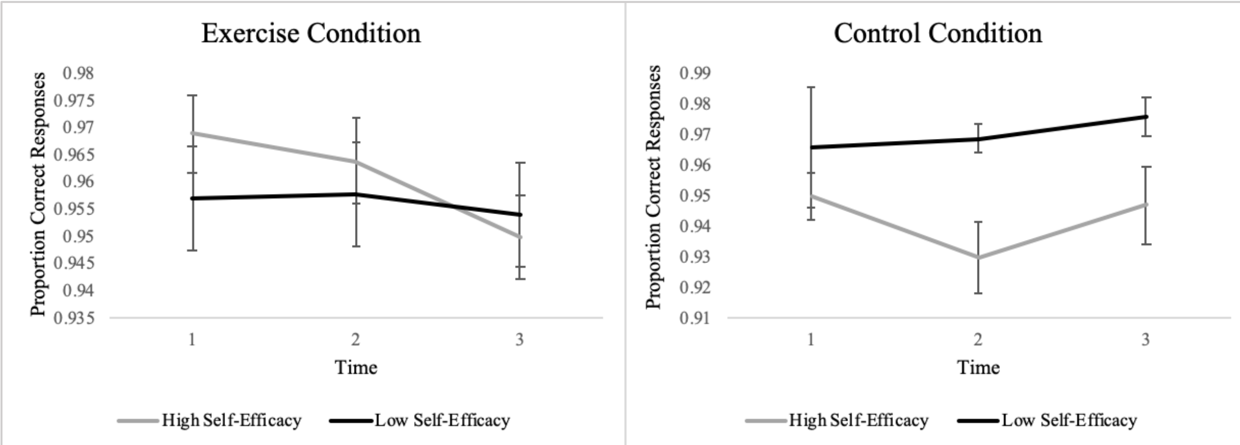

Figure 4. In the exercise condition there were no significant differences in Stroop task performance by self-efficacy group. In the control condition, participants low in self-efficacy performed better overall than those high in self-efficacy. Error bars represent standard error.

Chapter 4: Discussion

This study examined individual differences in executive functioning and psycho-emotional well-being among children with ADHD and how these differences may impact the effect of a short bout of exercise on executive functioning. Children with lower inhibitory control prior to the exercise intervention appeared to benefit the most from 10 minutes of exercise. Children's mood state also impacted the effect of exercise on executive functioning, whereas self-efficacy did not. Specifically, exercise appeared to minimize any initial effect that differences in positive mood had on executive functioning. This study was the first to examine how individual differences in inhibitory control, mood and self-efficacy impact the efficacy of acute exercise among children with ADHD.

Research Question 1: How do individual differences in inhibitory control influence the effect of acute exercise on executive functioning?

Individuals who scored lower on a measure of inhibitory control at pre-intervention saw greater improvements to their inhibitory control after 10 minutes of exercise than individuals higher in inhibitory control. The pattern of results suggests that exercise reduces initial differences in inhibitory control, as those with lower inhibitory control were no longer significantly different from those with higher inhibitory control at immediate post-intervention. The benefits of exercise are further demonstrated by the pattern of findings in the control condition, in which participants with lower inhibitory control at pre-intervention continued to perform worse than participants with higher inhibitory control throughout the study session.

These results support our initial hypothesis and are aligned with similar findings in adults and typically developing children (i.e. Drollette et al., 2014; Sibley & Etnier, 2007). Exercise appears to be most beneficial for those who need it most. This can be understood within an

Aptitude by Treatment Interaction (ATI) framework, meaning that different groups may react differently to the same treatment. In this case, participants with lower inhibitory control may have had more room for improvement than participants with higher inhibitory control. As such, participants with lower inhibitory control may have been more receptive to the intervention. Meanwhile, the higher performing group may not have needed an intervention to perform at their best and therefore was less receptive to the intervention.

A potential explanation as to why exercise may have been more beneficial for those with lower inhibitory control is that exercise may have led to greater changes in prefrontal cortical activity among those with lower inhibitory control. Similar findings were observed by Drollette et al. (2014), who found that typically developing children with lower inhibitory control, but not children with higher inhibitory control, exhibited larger P3 amplitudes following exercise compared to following a seated rest condition. P3 amplitudes are a brain activity measure derived using electroencephalogram (EEG) and are considered to reflect the intensity of attentional focus (Kok, 2001). This suggests that individuals who struggle with inhibitory control may be more affected by exercise on a neurological level than those who do not. These neurological changes may be reflected behaviourally as increased attentional focus, and therefore lead to improved performance on inhibitory control tasks. It is unclear why individuals low in inhibitory control might experience more neurological changes than individuals high in inhibitory control following exercise, but it has been observed that even given identical neuroelectric stimulation, individuals with weaker executive functions show a larger behavioural response than individuals with stronger executive functions (Tseng et al., 2012). This means that individuals low in inhibitory control may both experience larger neurological changes following exercise and be more behaviourally reactive to those changes compared to individuals higher in inhibitory control. However, additional research will need to be conducted to confirm these patterns and understand why they may occur.

What remains surprising, is the apparent lack of response to exercise from participants who were higher in inhibitory control. This is somewhat unexpected, given that studies consistently show improvements in executive functions following exercise across a variety of populations, including typically developing children and adults (i.e. Ellemberg & St. Louis-Deschenes, 2010; Kao et al., 2017). For example, Ludyga et al. (2017) found that children with and without ADHD both improved on an inhibitory control task following exercise. The children without ADHD had significantly better pre-intervention scores than those with ADHD, yet both groups improved following exercise. This contradicts the present findings, because individuals higher in inhibitory control did not improve following exercise. One possible reason for this discrepancy is the length of the exercise intervention. Studies that have shown improvements in inhibitory control among higher performing individuals have typically employed exercise durations longer than the 10 minutes used in the present study (i.e. 20 minutes in Ludyga et al., 2017; 30 minutes in Ellemberg & St. Louis-Deschenes, 2010). Higher performing individuals may need a longer duration of exercise to benefit.

The short duration of exercise used in this study may also have contributed to the short duration of the observed benefits. Though participants lower in inhibitory control were able to match the participants higher in inhibitory control immediately post-intervention, ten minutes later at delayed post-intervention they were back to their baseline level of performance. Similar findings have been previously observed, with longer-term cognitive benefits requiring bouts of exercise longer than 20 minutes (Chang et al., 2012b). This suggests that a longer bout, or repeated short bouts, may be necessary for sustained executive functioning benefits.

Research Question 2: How do individual differences in mood impact the effect of acute exercise on executive functioning?

Exercise appeared to counteract any initial effect of positive mood on inhibitory control. In the exercise condition, participants with higher positive mood performed better on the inhibitory control task prior to the intervention than participants with lower positive mood; however, immediately following exercise and after a delay there was no difference between the groups. In the control condition, there was no difference between groups at any timepoint. It is difficult to explain why participants in a more positive mood performed better prior to the intervention in the exercise condition but not in the control condition, given that participants had not yet been exposed to an intervention in either condition. It is possible that the baseline difference between individuals in the exercise condition is simply an artifact of low power. As mentioned above, we did not achieve our target sample size for this study, which means that there is a higher chance of detecting effects that would not truly exist in the wider population. This explanation is bolstered by the general lack of evidence to support the idea that positive mood could improve executive functioning. In fact, most studies have found that positive mood either has no effect, or actually leads to worsened performance on tasks of executive functioning (Martin & Kerns, 2011). However, prior studies examining the impact of mood on executive functioning have used mood inductions, rather than measures of existing mood states (Mitchell & Phillips, 2007; Dreisbach & Goschke, 2004). Because the present study measured participants' mood state rather than inducing a particular mood, it is possible that natural mood state impacts cognition differently than induced mood. This could account for the positive relationship between positive mood and inhibitory control prior to intervention in the exercise condition, though it would not explain the lack of relationship in the control condition.

As for negative mood, there were no differences in inhibitory control task performance between individuals in more versus less negative moods prior to the intervention in either the exercise or control conditions. There were also no differences between groups at immediate and delayed post-intervention in the control condition. In the exercise condition however, participants in a less negative mood outperformed participants in a more negative mood immediately following exercise. The reverse was true after a delay. The lack of baseline differences is consistent with some previous research finding that negative mood does not have a significant impact on executive functioning (Mitchell & Phillips, 2007), but the reasons for the interaction between time and group in the exercise condition are less clear. One possible explanation is that the participants who were in a more negative mood (who performed better after a delay) were anticipating the end of the experimental session. The negative mood state of these participants could be related to a lack of enjoyment or interest in the study and thus a motivation to finish the final executive functioning task quickly and end the session. This increased motivation to finish quickly may have translated to better performance, as the tasks are timed. In contrast, participants who were in a less negative mood may have been enjoying the study more and may therefore have been more motivated to participate to the best of their ability immediately following the exercise session.

Overall, the findings related to the effect of mood on the impact of exercise on inhibitory control are quite unclear. On the one hand, exercise appears to equalize baseline differences in the impact of positive mood on executive functioning, yet these baseline differences were only present in the exercise condition. On the other hand, a less negative mood appears to improve performance immediately after exercise, but there is an advantage to being in a more negative mood after a delay. In both cases, the results were unexpected and difficult to explain. A few possible explanations have been discussed, but further research with a larger sample size will be necessary to draw firmer conclusions about this research question. However, it is intriguing that there were several significant effects, which suggests that mood does have some impact on how exercise is affecting the executive functioning of children with ADHD, even if the exact parameters of this effect remains unclear.

Research Question 3: How do individual differences in self-efficacy impact the effect of acute exercise on executive functioning?

Contrary to our hypothesis, individual differences in state self-efficacy did not appear to impact the effect of an acute bout of exercise on executive functioning. However, these results were not too surprising, given that previous research on the impact of self-efficacy on executive functioning has yielded relatively small and specific effects (Themanson et al., 2011). The more robust findings in the self-efficacy and cognition literature have been in non-executive domains, such as mathematical fluency and language-concept formation (Bouffard-Bouchard, 2001). Our examination of the impact of exercise on the effect of self-efficacy on inhibitory control was a novel investigation, and was therefore largely exploratory. Future research on this topic could examine self-efficacy as a mediating factor in motivation for exercise. Prior work has found that children who are higher in self-efficacy are more motivated to participate in exercise (Gao et al., 2011). If self-efficacy does play a role in the relationship between cognition and exercise, then it may be more likely to be an indirect relationship through motivation. However, based on the current results, it is unlikely that self-efficacy has a directly meaningful impact on the relationship between exercise and executive function.

Implications

The results of this study suggest that acute exercise may foster the greatest inhibitory control benefits for those who need it the most. Among children with ADHD, individuals who were lower in inhibitory control appeared to improve more following exercise than those who were higher in inhibitory control. This finding has important implications for children with ADHD who struggle with executive functions. This study adds to the evidence supporting the positive relationship between exercise and cognition in children, especially those with cognitive and behavioural challenges (Sibley & Etnier, 2003; Cornelius et al., 2017). Though this study only demonstrated short-lived executive functioning benefits following acute exercise, repeated short bouts of exercise may add up to longer term benefits, or at least repeated short-term benefits. This could be significant for the quality of life of children with low inhibitory control, including children with ADHD for whom inhibitory control tends to be an important area of difficulty. Inhibitory control deficits have been associated with lower academic success, mental and physical health problems, and higher rates of risk-taking behaviour (Moffit et al., 2011). For children with ADHD, addressing needs in inhibitory control early-on has the potential to affect their academic, career, and life success in significant ways.

It is also important to recognize that a subset of participants in this study did not benefit from a short bout of exercise, namely participants with higher inhibitory control prior to the intervention. Other studies have repeatedly found that individuals in the normal or even above average range on cognitive tasks do benefit from exercise, however a time duration of longer than 10 minutes of exercise appears to be necessary (Chang et al., 2012b). This has practical implications for the utility of brief bouts of exercise. For example, due to time constraints in classrooms, exercise is often administered in bouts of only 5 to 10 minutes (Malvidi et al., 2020).

Based on our findings, these short bouts may only be beneficial for a subset of students. However, since the subset of students benefiting is likely to be the students who need it the most, these interventions still have value. In cases where classroom exercise can only be available to a small number of students, our findings suggest that students who are struggling the most with their inhibitory control should potentially be targeted for priority access to these resources, when they cannot be made available to all students.

Limitations and Future Directions

There are several important limitations to this study. Firstly, the sample size was quite small. Our goal was to include 30 participants; however, we were only able to recruit 16 due to the COVID-19 pandemic halting data collection efforts. This likely limited our power to detect effects, meaning that we cannot have as much confidence in the results as we could with a larger sample. In the future, we plan to test an additional 14 participants to reach our desired sample size. We also plan to test a group of 30 typically developing children using the same protocol to determine if the effects we observed in this study are unique to children with ADHD, or if similar patterns are evident in typically developing children. Relatedly, our data analysis did not directly compare the control and exercise conditions, which reduces our ability to make specific claims about differences between conditions. With a larger sample, we will be able to conduct a three-factor ANOVA, with time and condition as within-subjects factors and group as a between-subjects factor.

Beyond the present study, future research should examine other cognitive outcomes to determine if the observed effects are unique to inhibitory control, or if other executive and non-executive cognitive functions—such as working memory and academic skills—will be impacted in a similar way. Additionally, similar studies involving longer time durations of acute exercise (i.e. 20-30 minutes) would be useful to better understand the role of important individual difference factors and their interaction with exercise interventions. This would be informative because the present study leaves open the possibility that given a longer bout of exercise, individuals higher in inhibitory control might also improve. It would be useful to understand if any such improvements were different in magnitude compared to individuals lower in inhibitory control. Finally, future research should consider using a longitudinal design to determine if ongoing or repeated exercise results in greater cognitive improvements for individuals lower in inhibitory control compared to individuals higher in inhibitory control over time. This type of longitudinal research would be best suited for an applied setting, such as a classroom, and would allow researchers to understand if the potential real-world benefits of participating in regular exercise are greater for certain individuals than others.

Conclusions

This research was the first to our knowledge to examine the role of individual differences in inhibitory control, mood, and self-efficacy in response to exercise among children with ADHD. The results indicated that individuals with ADHD lower in inhibitory control may benefit more from an acute bout of exercise compared to individuals with ADHD higher in inhibitory control. In essence, acute exercise appeared to be most beneficial for those who need it most. Though self-efficacy did not affect the impact of exercise and results for mood were equivocal, this research still sheds important light on the ways in which individual differences can impact responses to exercise interventions.

References

Ahern, E., & Semkovska, M. (2017). Cognitive functioning in first-episode of major depressive disorder: A systematic review and meta-analysis. *Neuropsychology, 31*, 52-72.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders, 5th edition*. American Psychiatric Association.

Austin, M., Mitchell, P., & Goodwin, G. M. (2001). Cognitive deficits in depression: Possible implications for functional neuropathy. *British Journal of Psychiatry, 178,* 200-206.

Ashinkoff, B. K., & Abu-Akel, A. (2019). Hyperfocus: The forgotten frontier of attention. *Psychological Research*, doi.org/10.1007/s00426-019-01245-8.

Baddeley, A. (2010). Working memory. *Current Biology, 20,* 136-140.

Bachmann, C. J., Wijlaars, L. P., Kalverdijk, L. J., Bercu, M., Glaeske, G., Schuiling-Veninga, C. C., Hoffmann, F., Aagaard, L., & Zito, J. M. (2017). Trends in ADHD medication use in children and adolescents in five western countries, 2005-2012. *European Neuropsychopharmacology, 27,* 484-493.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*, 117-148.

Barkley, R. A. (1997). Behavioural inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 122,* 65-94.

Berlin, L., Bohlin, G., & Ryndell, A. (2004). Relations between inhibition, executive functioning, and ADHD symptoms: A longitudinal study from age 5 to 8.5 years. *Child Neuropsychology, 9,* 255-266.

Berwid, O. G., & Halperin, J. M. (2012). Emerging support for a role of exercise in attention-deficit/hyperactivity disorder intervention planning. *Current Psychiatry Reports*, *14*(5), 543-551.

Bledsoe, J. C., Semrud-Clikeman, M., & Pliszka, S. R. (2010). Response inhibition and academic abilities in typically developing children with Attention-deficit-hyperactivity disorder-combined subtype. *Archives of Clinical Neuropsychology, 25*(7), 671-679.

Bohlin, G., Nyberg, L., Janols, L.-O., & Berlin, L. (2004). How Well Do Measures of Inhibition and Other Executive Functions Discriminate Between Children With ADHD and Controls? *Child Neuropsychology (Neuropsychology, Development and Cognition: Section C), 10(1),* 1–13.

Borg, G. (1998). *Borg's perceived exertion and pain scales.* Human Kinetics.

Bouffard-Bouchard, T. (2001). Influence of self-efficacy on performance in a cognitive task. *The Journal of Social Psychology, 130*(3), 353-363.

Buelow, M. T. (2015). Predicting performance on the Columbia Card Task: Effects of personality characteristics, mood, and executive functions. *Assessment*, *22*(2), 178-187.

Burnford, N., Evans, S. W., & Wymbs, F. (2015). ADHD and emotion dysregulation among children and adolescents. *Clinical Child and Family Psychology Review, 18,* 185-217.

Byun, K., Hyodo, K., Suwabe, K., Kujach, S., Kato, M., & Soya, H. (2014). Possible influences of exercise-intensity-dependent increases in non-cortical hemodynamic variables on NIRS-based neuroimaging analysis during cognitive tasks. *Journal of Exercise Nutrition & Biochemistry*, *18*(4), 327.

Cairncross, M., & Miller, C. J. (2016). The effectiveness of mindfulness-based therapies for ADHD: A meta-analytic review. *Journal of Attention Disorders*, *24*(5), 627-643.

Canadian Mental Health Association. (2014). *Attention-deficit/hyperactivity disorder in children and youth.* https://www.heretohelp.bc.ca/sites/default/files/attention-deficit-hyperactivity-disorder-in-children-and-youth.pdf

Campbell, S. B., & von Stauffenberg, C. (2009). Delay and inhibition as early predictors of ADHD symptoms in third grade. *Journal of Abnormal Child Psychology, 37*, 1-15.

Carpenter, P. A., Just, M. A., & Reichle, E. D. (2000). Working memory and executive function: Evidence from neuroimaging. *Current Opinion in Neurobiology, 10,* 195-199.

Cerrillo-Urbina, A. J., García-Hermoso, A., Sánchez-López, M., Pardo-Guijarro, M. J., Santos Gómez, J. L., & Martínez-Vizcaíno, V. (2015). The effects of physical exercise in children with attention deficit hyperactivity disorder: A systematic review and meta-analysis of randomized control trials. *Child: Care, Health and Development*, *41*(6), 779-788.

Chang, Y. K., Liu, S., Yu, H., & Lee, Y. (2012a). Effect of acute exercise on executive function in children with attention deficit hyperactivity disorder. *Archives of Clinical Neuropsychology*, *27*(2), 225-237.

Chang, Y. K., Labban, J. D., Gapin, J. I., Etnier, J. L. (2012b). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, 1453, 87-101.

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational Research Methods*, *4*(1), 62-83.

Chronis, A., Jones, H. A., & Raggi, V. (2006). Evidence-based psychosocial treatments foc children and adolescents with attention-deficit/hyperactivity disorder. *Clinical Psychology Review*, *26*, 486-502.

Conzelmann, A., Mucha, R. F., Jacob, C. P., Weyers, P., Romanos, J., Gerdes, A. B., Baehne, C. G., Boreatti-Hummer, A., Heine, M., Alpers, G. W., Warnke, A., Fallgatter, A. J., Lesch, K., & Pauli, P. (2009). Abnormal affective responsiveness in attention-deficit/hyperactivity disorder: Subtype differences. *Biological Psychiatry, 65,* 578-585.

Cornelius, C., Fedewa, A. L., & Ahn, S. (2017). The effect of physical activity on children with ADHD: A quantitative review of the literature. *Journal of Applied School Psychology, 33*(2), 136-170.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135-168.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(2), 343-353.

Drollette, E. S., Scudder, M. R., Raine, L. B., Moore, R. D., Saliba, B. J., Pontifex, M. B., & Hillman, C. H. (2014). Acute exercise facilitates brain function and cognition in children who need it most: An ERP study of individual differences in inhibitory control capacity. *Developmental Cognitive Neuroscience, 7,* 53-64.

Ellemberg, D., & St-Louis-Deschenes, M. (2010). The effect of acute exercise on cognition during development. *Psychology of Sport and Exercise, 11*(2), 122-126.

Erikson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., ... Powell, K. E. (2019). Physical activity, cognition, and brain outcomes: A review of the 2018 physical activity guidelines. *Medicine and Science in Sports and Exercise, 51*(6), 1242-1251.

Evans, S. W., Owens, J. S., & Bunford, N. (2014). Evidence-based psychosocial treatments for children and adolescents with attention-deficit/hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology, 43*(4), 527-551.

Franke, B., Micheline, G., Asherson, P., Banaschewski, T., Bilbow, A., Buitelaar, J. K., Cormand, B., Farone, S. V., Ginsberg, Y., Haavik, J., Kuntsi, J., Larsson, H., Lesch, K., Ramos-Quiroga, J. A., Rethelyi, J. M., Ribases, M., & Reif, A. (2018). Live fast, die young? A review on the developmental trajectories of ADHD across the lifespan. *European Neuropsychoparmacology, 28*(10), 1059-1088.

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex, 86,* 186-204.

Fritz, K. M., & O'Connor, P. J. (2016). Acute exercise improves mood and motivation in young men with ADHD symptoms. *Medicine and Science in Sports and Exercise, 48*(6), 1153-1160.

Gabel, M. S., & McAuley, T. (2018). Does mood help or hinder executive functions? Reactivity may be the key. *Personality and Individual Differences, 128*, 94-99.

Gambin, M., & Swiecicka, M. (2015). Relationships of self-efficacy beliefs to executive functions, hyperactivity-impulsivity and inattention in school-ages children. *Polish Journal of Applied Psychology, 13,* 33-42.

Gao, Z., Lochbaum, M., & Podlog, L. (2011). Self-efficacy as a mediator of children's achievement motivation and in-class physical activity. *Perceptual & Motor Skills, 113,* 969-981.

Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical activity, affect, and cognition in children with symptoms of ADHD. *Journal of Attention Disorders, 20,* 151-162.

Giles, G. E., Brunye, T. T., Eddy, M. D., Mahoney, C. R., Gagnon, S. A., Taylor, H. A., & Kanarek, R. B. (2014). Acute exercise increases oxygenated and deoxygenated hemoglobin in the prefrontal cortex. *Cognitive Neuroscience and Neuropsychology, 25,* 1320-1325.

Gligoroska, J., & Manchevska, S. (2012). The effect of physical activity on cognition: Physiological mechanisms. *Materia Socio Medica, 24*, 198-202.

Guerts, H. M., Verte, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2004). How specific are executive function deficits in attention deficit hyperactivity disorder and autism? *Journal of Child Psychology and Psychiatry, 45*(4), 836-854.

Hale, J. B., Reddy, L. A., Semrud-Clikeman, M., Hain, L. A., Whitaker, J., Morley, J., Lawrence, K., Smith, A., & Jones, N. (2011). Executive impairment determines ADHD medication response: Implications for academic achievement. *Journal of Learning Disabilities, 44*(2), 196-212.

Halleland, H. B., Sorensen, L., Posserud, M., Haavik, J., & Lundervold, A. J. (2019). Occupational status is compromised in adults with ADHD and psychometrically defined executive function deficits. *Journal of Attention Disorders, 23*, 76-86.

Harpin, V., Mazzone, L., Raynaud, J. P., Kahle, J., & Hodgkins, P. (2016). Long-term outcomes of ADHD: A systematic review of self-esteem and social function. *Journal of Attention Disorders, 20*(4), 295-305.

Hauck, T. S., Lau, C., Wing, L. L., Kurdyak, P., Tu, K. (2017). ADHD treatment in primary care: Demographic factors, medication trends, and treatment predictors. *The Canadian Journal of Psychiatry*, *62*(6), 393-402.

Hillman, C. H., Kamijo, K., & Scudder, M. (2011). A review of chronic and acute physical activity participation on neuroelectric measures of brain health and cognition during childhood. *Preventative Medicine*, *52*, 521-528.

Hillman, C. H., Pontifex., M. B., Castelli, D. M., Khan., N. A., Raine, L. B., Scudder, M. R., Drollette, E. S., Moore, R. D., Wu, C., & Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics*, *134*(4), 1063-1071.

Hoza, B., Smith, A. L., Shoulburg, E., Linnea, K. S., Dorsch, T. E., Blazo, J. A., Alerding, C. M., & McCabe, G. P. (2014). A randomized trial examining the effects of aerobic physical activity on attention-deficit/hyperactivity disorder symptoms in young children. *Journal of Abnormal Child Psychology*, *43*, 655-667.

Johnson, K. A., White, M., Wong, P. H., & Murrihy, C. (2020). Aspects of attention and inhibitory control are associated with on-task classroom behaviour and behavioural assessments by both teachers and parents in children with high and low symptoms of ADHD. *Child Neuropsychology*, *26*, 219-241.

Kao, S., Westfall, D., Soneson, J., Gurd, B., & Hillman, C. (2017). Comparison of the acute effects of high-intensity interval training and continuous aerobic walking on inhibitory control. *Psychophysiology*, *54*, 1335-1345.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology*, *38*, 557-577.

Konishi, S., Nakajima, K., Uchida, I., Kameyama, M., Nakahara, K., Sekihara, K., & Miyashita, Y. (1998). Transient activation of inferior prefrontal cortex during cognitive set shifting. *Nature Neuroscience, 1,* 80-84.

Kowalski, K. C., Crocker, P. R., & Donen, R. M. (2004). The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual. *College of Kinesiology, University of Saskatchewan, 87,* 1-38.

Lambek, R., Tannock, R., Dalsgaard, S., Trillingsgaaud, A., Damm, D., & Thomsen, P. (2011). Executive dysfunction in school-age children with ADHD. *Journal of Attention Disorders, 15,* 646-655.

Lansbergen, M. M., Kenemans, J. L., & Van Engeland, H. (2007). Stroop interference and attention-deficit/hyperactivity disorder: A review and meta-analysis. *Neuropsychology, 21*, 251-262.

Lipszyc, J., & Schacher, R. (2010). Inhibitory control and psychopathology: A meta-analysis of studies using the stop signal task. *Journal of the International Neuropsychological Society, 16*(6), 1064-1076.

Ludyga, S., Brand, S., Gerber, M., Weber, P., Brotzmann, M., Habibifar, F., & Pushe, U. (2017). An event-related potential investigation of the acute effects of aerobic and coordinative exercise on inhibitory control in children with ADHD. *Developmental Cognitive Neuroscience, 28,* 21-28.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

Machado, F. A., & Denadai, B. S. (2011). Validity of maximum heart rate prediction equations for children and adolescents. *Arquivos brasileiros de cardiologia, 97*(2), 136-140.

Malvidi, M. F., Drew, R., Morgan, P. J., Lubans, D. R., Schmidt, M., & Riley, N. (2020). Effects of different types of classroom physical activity breaks on children's on-task behaviour, academic achievement, and cognition. *Acta Paediatrica, 109,* 158-165.

Martel, M., Nikolas, M., & Nigg, J. T. (2007). Executive function in adolescents with ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry , 46,* 1437-1444.

Martin, E. A., & Kerns, J. G. (2011). The influence of positive mood on different aspects of cognitive control. *Cognition & Emotion, 25*(2), 265-279.

McCandless, S., & O'Laughlin, L. (2007). The clinical utility of the Behaviour Rating Inventory of Executive Function (BRIEF) in the diagnosis of ADHD. *Journal of Attention Disorders, 10,* 381-389.

Miley, W. M., & Spinella, M. (2006). Correlations among measures of executive function and positive psychological attributes in college students. *The Journal of General Psychology, 133*, 175-182.

Miller, M., Nevado-Montenegro, A., & Hinshaw, S. P. (2012). Childhood executive function continues to predict outcomes in young adult females with and without childhood-diagnosed ADHD. *Journal of Abnormal Child Psychology, 40,* 657-668.

Mitchell, R. L., & Phillips, L. H. (2007). The psychological, neurochemical and functional neuroanatomical mediators of the effects of positive and negative mood on executive functions. *Neuropsychologia, 45,* 617-629.

Moffit, T. E., Arsenault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences, 108*(7), 2693-2698.

Morris, S. S., Musser, E. D., Tenenbaum, R. B., Ward, A. R., Martinez, J., Raiker, J. S., Coles., E. K., & Riopelle, C. (2020). Emotion regulation via the autonomic nervous system in children with attention-deficit/hyperactivity disorder (ADHD): Replication and extension. *Journal of Abnormal Child Psychology, 48,* 361-373.

Munakata, Y., Herd, S. A., Chatham, C. H., Depue, B. E., Banich, M. T., & O'Reilley, R. C. (2011). A unified framework for inhibitory control. *Trends in Cognitive Sciences, 15,* 453-459.

Neudecker, C., Mewes, N., Reimers, A. K., & Woll, A. (2019). Exercise interventions in children and adolescents with ADHD: A systematic review. *Journal of Attention Disorders, 23*(4), 307-324.

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: Evidence from Stroop and fluency tasks. *Emotion, 2,* 12-22.

Piepmeier, A. T., Shih, C., Wheldon, M., Williams, L., Davis, M. E., Henning, D. A., Park, S., Calkins, S., & Etnier, J. (2015). The effect of acute exercise in children on cognitive performance in children with and without ADHD. *Journal of Sport and Health Science, 4,* 97-104.

Polanczyk, G., de Lima, M. S., Horta, B. L., Biederman, J., & Rohde, L. A. (2007). The worldwide prevalence of ADHD: A systematic review and metaregression analysis. *American Journal of Psychiatry, 164,* 942-948.

Pollack, Y., Dekkers, T. J., Shoham, R., & Huizenga, H. M. (2019). Risk-taking behaviour in attention-deficit/hyperactivity disorder (ADHD): A review of potential underlying mechanisms and of interventions. *Current Psychiatry Reports, 21,* Article 33.

Pontifex, M. B., Saliba, B. J., Raine, L. B., Picchietti, D. L., & Hillman, C. H. (2013). Exercise improves behavioural, neurocognitive, and scholastic performance in children with attention-deficit/hyperactivity disorder. *Journal of Pediatrics, 162,* 543-551.

Reitan, R. M., & Wolfson, D. (2004). The trail making test as an initial screening procedure for neuropsychological impairment in older children. *Archives of Clinical Neuropsychology, 19,* 281-288.

Robitaille, A., Muniz, G., Lindwall, M., Piccinin, A. M., Hoffman, L., Johansson, B., & Hofer, S. M. (2014). Physical activity and cognitive functioning in the oldest old: Within- and between-person cognitive activity and psychosocial mediators. *European Journal of Aging, 11,* 333-347.

Roell, M., Viarouge, A., Houde, O., & Borst, G. (2017). Inhibitory control and decimal number comparison in school-aged children. *PLOS one*, *12*(11): e0188276.

Rosenberg, M. D., Finn, E. S., Scheinost, D., Papademetris, X., Shen, X., Constable, R. T., & Chun, M. M. (2016). A neuromarker of sustained attention from whole brain functional connectivity. *Nature Neuroscience, 19,* 163-171.

Rucklidge, J. J. (2010). Gender differences in attention-deficit/hyperactivity disorder. *Psychiatric Clinics, 33,* 357-373.

Salkind, N. (2010). Encyclopedia of Research Design. dx.doi.org/10.4135/9781412961288.n59

Sanchez-Cubillo, I., Perianez, J. A., Adrover-Roig, D., Rodriguez-Sanchez, J. M., Rios-Lago, M., Tirapu, J., & Barcelo, F. (2009). Construct validity of the trail making test: Role of task-switching, working memory, inhibition/interference control, and visuomotor abilities. *Journal of the International Neuropsychological Society, 15,* 438-540.

Shier, A. C., Reichenbacjer, T., Ghuman, H. S., & Ghuman, J. K. (2013). Pharmacological treatment of attention deficit hyperactivity disorder in children and adolescents: Clinical Strategies. *Journal of Central Nervous System Disease, 5,* 1-17.

Sibley, B. A., & Beilock, S. L. (2007). Exercise and working memory: An individual differences investigation. *Journal of Sport & Exercise Psychology, 29*(6), 783-791.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.

Simpson, T., Cronin, L., Ellison, P., Carnegie, E., & Marchant, D. (2020). A test of optimal theory on young adolescents' standing long jump performance and motivation. *Human Movement Science, 72,* ID 102651.

Smith, A. L., Hoza, B., Linnea, K., McQuade, J. D., Tomb, M., Vaughn, A. J., Shoulberg, E. K., & Hook, H. (2013). Pilot physical activity intervention reduces severity of ADHD symptoms in young children. *Journal of Attention Disorders, 17*(1), 70-82.

Snow, R. E. (1991). Aptitude-treatment interaction as a framework for research on individual differences in psychotherapy. *Journal of Consulting and Clinical Psychology, 59,* 205-216.

Soga, K., Shishido, T., & Nagatomi, R. (2015). Executive function during and after acute moderate aerobic exercise in adolescents. *Psychology of Sport and Exercise, 16,* 7-17.

Spencer, T. J. (2006). ADHD and comorbidity in childhood. *Journal of Clinical Psychiatry, 67,* 27-31.

Stillman, C. M., Cohen, J., Lehman, M. E., & Erikson, K. I. (2016). Mediators of physical activity on neurocognitive function: A review at multiple levels of analysis. *Frontiers in Human Neuroscience, 10,* ID 626.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643-662.

Stuss, D. T. (2011). Functions of the frontal lobes: Relation to executive functions. *Journal of the International Neuropsychological Society, 17*(5), 759-765.

Themanson, J. R., Pontifex, M. B., Hillman, C. H., & McAuley, E. (2011). The relation of self-efficacy and error-related self-regulation. *International Journal of Psychophysiology, 80,* 1-10.

Tomporoski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review, 20,* 111-131.

Toomey, S. L., Sox, C. M., Rusinak, D., & Finkelstein, J. A. (2012). Why do children with ADHD discontinue their medication? *Clinical Pediatrics, 51*(8), 763-769.

Tseng, P., Hsu, T., Chang, C., Tzeng, O., Hung, D., Muggleton, N., Walsh, V., Liang, W., Cheng, S., & Juan, C. (2012). Unleashing potential: Transcranial direct current stimulation over the right posterior parietal cortex improves change detection in low performing individuals. *Journal of Neuroscience, 32*(31), 10554-10561.

Vance, D. E., Wadley, V. G., Ball, K. K., Roenker, D. L., & Rizzo, M. (2005). The effects of physical activity and sedentary behavior on cognitive health in older adults. *Journal of Aging and Physical Activity, 13,* 294-313.

Vaidya, C. (2011). Neurodevelopmental abnormalities in ADHD. In C. Stanford & R. Tannock (Eds.), *Behavioural Neuroscience of Attention Deficit Hyperactivity Disorder and Its Treatment* (pp. 49-66). Springer Berlin Heidelberg.

Waxmonsky, J., Pelham, W. E., Gnagy, E., Cummings, M. R., O'Connor, B., Majumdar, A., Verley, J., Hoffman, M. T., Massetti, G. A., Burrows-MacLean, L., Fabiano, G. A., Waschbusch, D. A., Chacko, A., Arnold, F. W., Walker, K. S., Garefino, A. C., & Robb, J. A. (2008). The efficacy and tolerability of methylphenidate and behaviour modification in children with attention-deficit/hyperactivity disorder and severe mood dysregulation. *Journal of Child & Adolescent Psychopharmacology, 18*(6), 573-588.

Williams, P., & Lord, S. R. (1997). Effects of group exercise on cognitive functioning and mood in older women. *Australian and New Zealand Journal of Public Health, 21,* 45-52.

Williamson, D., Dewey, A., & Steinberg, H. (2001). Mood change through physical exercise in nine- to ten-year-old children. *Perceptual & Motor Skills, 93,* 311-316.

Willoughby, M. T., Wylie, A. C., & Little, M. H. (2019). Testing longitudinal associations between executive function and academic achievement. *Developmental Psychology, 55,* 767-779.

Wind, A. E., Takken, T., Helders, P. J., & Englebert, R. H. (2010). Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *European Journal of Pediatrics, 169,* 281-287.

Yamazaki, Y., Sato, D., Yamashiro, K., Tsubaki, A., Takehara, N., Uetake, Y., Nakano, S., Maruyama, A., & Kotozaki., Y. (2018). Inter-individual differences in working memory improvement after acute mild and moderate aerobic exercise. *PLOS One, 13,* e0210053.

Young, S., & Amarasinghe, J. M. (2010). Non-pharmacological treatments for ADHD: A lifespan approach. *Journal of Child Psychology and Psychiatry, 51*(2), 116-133.

Appendices

Appendix A

Incongruent Stroop Task

BLACK	YELLOW
BLUE	PURPLE
ORANGE	BROWN
RED	RED
PINK	PINK
BLUE	ORANGE
GREEN	GREY
GREY	GREEN
BROWN	GREEN
BLUE	BLACK
PURPLE	ORANGE
BLACK	GREY
GREY	PINK
ORANGE	YELLOW
YELLOW	BLUE

Appendix B

Profile of Mood States

FEELING	Not at all	A little	Moderate	Quite a bit	Extremely
Active	1	2	3	4	5
Awake	1	2	3	4	5
Bored	1	2	3	4	5
Energetic	1	2	3	4	5
Excited	1	2	3	4	5
Friendly	1	2	3	4	5
Happy	1	2	3	4	5
Lonely	1	2	3	4	5
Sad	1	2	3	4	5
Tired	1	2	3	4	5
Unhappy	1	2	3	4	5

Note: Items measuring positive mood included: Active, Awake, Energetic, Excited, Friendly, and Happy. Items measuring negative mood included: Bored, Lonely, Sad, Tired, and Unhappy.

Appendix C

General Self-Efficacy Scale

	Strongly Disagree				Strongly Agree
I will be able to achieve most of the goals I have set for myself	☐	☐	☐	☐	☐
When facing difficult tasks, I am certain that I will accomplish them	☐	☐	☐	☐	☐
In general, I think that I can obtain outcomes that are important to me	☐	☐	☐	☐	☐
I believe I can succeed at most any endeavor to which I set my mind	☐	☐	☐	☐	☐
I will be able to successfully overcome many challenges	☐	☐	☐	☐	☐
I am confident that I can perform effectively on many different tasks	☐	☐	☐	☐	☐
Compared to other people, I can do most tasks very well	☐	☐	☐	☐	☐
Even when things are tough, I can perform quite well	☐	☐	☐	☐	☐

Appendix D

Physical Activity Questionnaire

Physical Activity Questionnaire (PAQ-C): Physical Activity in the Last 7 Days

Characteristic	**Frequency (%)**
Skipping	
0	9 (56.3%)
1	4 (25%)
2	1 (6.3%)
3	1 (6.3%)
4	1 (6.3%)
Rowing	
0	15 (93.8%)
1	1 (6.3%)
Inline Skating	
0	15 (93.8%)
1	1 (6.3%)
Tag	
0	5 (31.3%)
1	7 (43.8%)
2	1 (6.3%)
3	2 (12.5%)
4	1 (6.3%)
Walking	
0	3 (18.8%)
1	5 (31.3%)
2	2 (12.5%)
3	3 (18.8%)
4	3 (18.8%)
Biking	
0	7 (43.8%)
1	2 (12.5%)
2	3 (18.8%)
3	4 (25%)
4	
Jogging	
0	6 (37.5%)
1	2 (12.5%)
2	3 (18.8%)

3	3 (18.8%)
4	1 (6.3%)
5	1 (6.3%)
Aerobics	
0	15 (93.8%)
1	1 (6.3%)
Swimming	
0	10 (62.5%)
1	2 (12.5%)
2	3 (18.8%)
3	1 (6.3%)
Baseball	
0	15 (93.8%)
1	1 (6.3%)
Dance	
0	11 (68.8%)
1	2 (12.5%)
2	2 (12.5%)
3	1 (6.3%)
Football	
0	14 (87.5%)
1	1 (6.3%)
2	1 (6.3%)
Badminton	
0	15 (93.8%)
1	1 (6.3%)
Skateboarding	
0	16 (100%)
Soccer	
0	13 (81.3%)
1	2 (12.5%)
2	1 (6.3%)
Street Hockey	
0	16 (100%)
Volleyball	
0	14 (87.5%)

1	2 (12.5%)
Floor Hockey	
0	14 (87.5%)
1	1 (6.3%)
2	1 (6.3%)
Basketball	
0	11 (68.8%)
1	3 (18.8%)
2	1 (6.3%)
3	1 (6.3%)
Ice Skating	
0	15 (93.8%)
1	1 (6.3%)
Country Skiing	
0	16 (100%)
Activity Within Last 7 Days During PE Class	
I don't do PE	2 (12.5%)
Hardly ever	4 (25%)
Sometimes	4 (25%)
Quite often	3 (18.8%)
Always	3 (18.8%)
Activity During Recess	
Sat down	3 (18.8%)
Stood around	5 (31.3%)
Ran or played a bit	2 (12.5%)
Ran and played quite a bit	2 (12.5%)
Ran and played hard	4 (25%)
Activity During Lunch	
Sat down	10 (62.5%)
Stood around	2 (12.5%)
Ran or played a bit	1 (6.3%)
Ran and played quite a bit	3 (18.8%)
Ran and played hard	
How many days right after school were you active?	
0	6 (37.5%)
1	1 (6.3%)
2-3	4 (25%)
4	2 (12.5%)

5	3 (18.8%)
How many days in the evening were you active?	
0	6 (37.5%)
1	2 (12.5%)
2-3	4 (25%)
4	1 (6.3%)
5	3 (18.8%)
On the weekend how many times were you active?	
0	5 (31.3%)
1	2 (12.5%)
2-3	2 (12.5%)
4-5	3 (18.8%)
6 or more	4 (25%)
How often did you do activity on Monday?	
0	2 (12.5%)
1	4 (25%)
2	6 (37.5%)
3	2 (12.5%)
4	2 (12.5%)
How often did you do activity on Tuesday?	
0	3 (18.8%)
1	4 (25%)
2	3 (18.8%)
3	5 (31.3%)
4	1 (6.3%)
How often did you do activity on Wednesday?	
0	2 (12.5%)
1	3 (18.8%)
2	3 (18.8%)
3	3 (18.8%)
4	5 (31.3%)
How often did you do activity on Thursday?	
0	3 (18.8%)
1	3 (18.8%)
2	7 (43.8%)
3	2 (12.5%)
4	1 (6.3%)
How often did you do activity on Friday?	
0	2 (12.5%)

1	6 (37.5%)
2	2 (12.5%)
3	2 (12.5%)
4	4 (25%)
How often did you do activity on Saturday?	
0	6 (37.5%)
1	3 (18.8%)
2	2 (12.5%)
3	3 (18.8%)
4	2 (12.5%)
How often did you do activity on Sunday?	
0	7 (43.8%)
1	2 (12.5%)
2	2 (12.5%)
3	1 (6.3%)
4	4 (25%)

Appendix E

Study Procedures

Appendix F

Ratings of Perceived Physical Exertion

Ratings of Perceived ***PHYSICAL*** Exertion (RPE)

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human kinetics.

0 Nothing at all

0.3

0.5 Extremely weak

1 Very weak

1.5

2 Weak

2.5

3 Moderate

4

5 Strong

6

7 Very Strong

8

9

10 Extremely Strong

11

12 Absolute Maximum

Date: 15 March 2019

To: Dr Barbara Fenesi

Project ID: 113304

Study Title: Understanding the effects of acute exercise and mindfulness on cognitive functioning in children with ADHD using advanced functional imaging techniques

Application Type: HSREB Initial Application

Review Type: Full Board

Meeting Date: 15/Jan/2019

Date Approval Issued: 15/Mar/2019

REB Approval Expiry Date: 15/Mar/2020

Dear Dr Barbara Fenesi

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date
Appendix 10 - Affect	Other Data Collection Instruments	Received March 14, 2019
Appendix 11 - Motivation Questionnaire	Other Data Collection Instruments	Received March 14, 2019
Appendix 12 - Self-efficacy	Other Data Collection Instruments	Received March 14, 2019
Appendix 13 - Mood Questionnaire	Other Data Collection Instruments	Received March 14, 2019
Appendix 2 - Vanderbilt Assessment	Paper Survey	Received March 14, 2019
Appendix 3 - C-PAQ	Paper Survey	Received March 14, 2019
Appendix 4 - Demographics and Medication (1)	Paper Survey	Received March 14, 2019
Appendix 5 - Stroop Task	Other Data Collection Instruments	Received March 14, 2019
Appendix 6 - Trail Making Task	Other Data Collection Instruments	Received March 14, 2019
Appendix 9 - Rating of Perceived Exertion	Other Data Collection Instruments	Received March 14, 2019
Assent ADHD mar 13	Assent Form	Received March 14, 2019
Assent Control mar 13	Assent Form	Received March 14, 2019
EmailAttachment_12.9 (3)	Email Script	Received March 14, 2019
LOI-C (Control) Mar 13	Written Consent/Assent	Received March 14, 2019
LOI-C(ADHD)	Written Consent/Assent	Received March 14, 2019
RecruitmentFlyer_ADHDGroup_12.5 (2)	Recruitment Materials	09/Feb/2019
RecruitmentFlyer_Age-matchedcontrol_12.5(2)	Recruitment Materials	09/Feb/2019
Study Protocol	Protocol	08/Feb/2019
Telephone_Script_12.9(1)	Telephone Script	Received March 14, 2019

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

MADELINE CRICHTON

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EDUCATION

2019-2021 **M.A. (Candidate), School & Applied Child Psychology**
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2018-2019 **M.A.Sc., Developmental & Communication Science**
University of Waterloo

2014-2018 **B. A. (Hon), Psychology**
University of Waterloo

HONOURS AND AWARDS

2020-2021	SSHRC Canada Graduate Scholarship - Master's
2020-2021	Ontario Graduate Scholarship *(declined)*
2018	NSERC Undergraduate Student Research Award
2018	Certificate of Academic Excellence - Canadian Psychological Association
2018	Honours Thesis Award - University of Waterloo Psychology Department
2018	Currie Scholarship
2014-2015	Waterloo County Entrance Scholarship
2014	University of Waterloo President's Scholarship of Distinction

CONFERENCE PRESENTATIONS

Crichton, M., Bigelow, H., Gottlieb, M., & Fenesi, B. (2020, March). *The impact of individual differences in cognitive and psycho-emotional functioning on the effect of acute physical activity in children with ADHD.* Paper presented at the Robert MacMillan Symposium in Education, Western University, London, ON, Canada.

TEACHING EXPERIENCE

Teaching Assistant
Winter 2019 Developmental Psychology, University of Waterloo
Fall 2018 Developmental Psychology, University of Waterloo

Guest Lecturer

2018 *Infant Temperament*, Developmental Psychology, University of Waterloo

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2020-Present **Tutor**
London Learning Disabilities Association
"Read-Up" program for students with learning disabilities in reading

2019-Present **Crisis Responder**
Kids Help Phone/Crisis Text Line
Volunteer for crisis texting service

2018 **Lab Manager**
Infant & Child Studies Group; University of Waterloo
Supervisors: Dr. Stephanie Denison & Dr. Katherine White

2018 **Program Facilitator**
Westmount Public School
Social skills and self-regulation program for grades 4-6

2016-2017 **Research Assistant**
Self-Attitudes Lab; University of Waterloo
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SERVICE & MENTORSHIP

2020-2021 Canadian Psychological Association Graduate Student Mentor

2019 Abstract Reviewer; University of Waterloo Symposium on Aging Research

KNOWLEDGE TRANSLATION

2020 Panelist, "Preparing for Graduate School as an Undergraduate in Psychology at the University of Waterloo"

2019 Co-facilitator, Kitchener Public Library Language Development Games Night

2019 Co-presenter, "Child-Friendly Spaces" at the Waterloo Park Advisory Committee